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International Waste Minimization Approaches & Policies to Metal Plating

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ERRATUM

PREFACE

This document was developed by the United States Environmental Protection Agency (U.S. EPA), Office of Solid Waste, Waste Minimization Branch.

The Agency would like to acknowledge Dr. Keith Legg of BIRL, Northwestern University; Dr. Arnold H. Deutchman, BEAMALLOY Corporation; Canada, OECD Secretariat staff; and the American Electroplaters and Surface Finishers Society for the helpful comments they provided on this document.

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DISCLAIMER

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DISCLAIMER

This document has been subjected to U.S. Environmental Protection Agency's peer and administrative review and approved for publication. This document is intended as advisory guidance only in developing approaches for pollution prevention. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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LIST OF EXHIBITS

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LIST OF ACRONYMS AND ABBREVIATIONS

ABC	Activity-based costing
ACE	Agriculture in Concert with the Environment
AESF	American Electroplaters and Surface Finishers Society
AFB	Air Force Base
BAT	Best available technique/technology
BPC	Biparting cover
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
CTSAs	Cleaner technology substitutes assessments
CVD	Chemical vapor deposition
CVR	Manual cover
CWA	Clean Water Act
DEP	Department of Environmental Protection
DOD	U.S. Department of Defense
DOE	Department of the Environment (United Kingdom)
DfE/DFE	Design for the Environment
DTI	Department of Trade and Industry
DWL	Dwell
EC	European Community
EEM	Energy, Environment, and Manufacturing
EMAP	Environmental Monitoring and Assessment Program
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESP	Electrostatic Precipitator
EST	Eastern Standard Time
FBR	Freeboard ratio
FR	Federal Register
FRD	Freeboard refrigeration device
gpd	Gallons per day
HAP	Hazardous air pollutant
HCFCs	Hydrochlorofluorocarbons
HMIP	Her Majesty's Inspectorate of Pollution

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

HSWA	Hazardous and Solid Waste Amendments
HVOF	High velocity oxygenated fuel
HWRIC	Illinois Hazardous Waste Reduction Information Center
IBED	Iron beam enhanced deposition
ICOLP	Industry Cooperative for Ozone Layer Protection
ICPIC	International cleaner production information clearinghouse
IMOF	Interim Multilateral Ozone Fund
IRR	Internal rate of return
IPPC	Integrated pollution prevention and control
LCC	Life cycle costing
LLCHD	Lincoln-Lancaster County Health Department
LQG	Large quantity generator
MACT	Maximum achievable control technology
MOE	Ministry of the Environment
MSW	Municipal solid waste
NAFTA	North American Free Trade Agreement
NAMF	National Association of Metal Finishers
NESHAPS	National Emission Standards for Hazardous Air Pollutants
$NICE^3$	National Industrial Competitiveness Through Efficiency: Energy, Environment and Economics
NMEN	National Material Exchange Network
NPDES	National Pollutant Discharge Elimination System
NPV	Net present value
NRA	National Rivers Authority
ODS	Ozone depleting substances
OECD	Organisation for Economic Cooperation and Development
OTA	Office of Technical Assistance
P2	Pollution prevention
PCB	Polychlorinated biphenyl
PERC	Perchloroethylene
PFCs	Perfluorocarbons
PG	Provincial government
PIES	Pollution Prevention Information Exchange System
POTW	Publicly owned treatment work
PPA	Pollution Prevention Act
PPCD	Pollution prevention control group
PPIC	Pollution Prevention Information Clearinghouse

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

PPIS	Pollution Prevention Incentives for States
PV	Present valve
PVD	Plasma vapor deposition
RCRA	Resource Conservation and Recovery Act
RRD	Reduced room draft
SARA	Superfund Amendments and Reauthorization Act
SEDUE	Secretaria de Desarrollo Urbano y Ecologia
SEP	Supplemental environmental program
SFT	State Pollution Control Authority
SHV	Superheated vapor
SIC	Standard industrial code
SIP	Sustainable industry project
SMEs	Small and medium enterprises
SRRP	Source reduction review project
TCA	1,1,1 trichloroethane
TCA	Total cost assessment
TCE	Trichloroethylene
TDS	Total dissolved solids
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
U.K.	United Kingdom
UNEP	United Nations Environment Programme
US/U.S.	United States
USC	United States Code
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
VOC	Volatile organic carbon
WMPG	Waste Management Policy Group
WRA	Waste Regulation Authority
WREAFS	Waste Reduction Evaluations at Federal Sites
WRITAR	Waste Reduction Institute for Training and Applications Research, Inc.

1.0 INDUSTRY OVERVIEW

1.1 Metal Plating Industry

Metal finishing operations are employed at some point during the manufacture of essentially all metal products. The manufacturing industries that rely most heavily on metal plating and finishing processes include fabricated metal products (e.g., metal cans, fasteners, tools, metal furniture), common machinery (e.g., engines, farm equipment, construction equipment, manufacturing machinery), electronic machinery (e.g., computers, office equipment, audio and visual electronics), household appliance (e.g., washing machines, refrigerators, small kitchen appliances), ground and water transportation equipment (e.g., automobiles, trucks, rail vehicles, boats), aerospace equipment (e.g., aircraft, satellites), and miscellaneous manufacturing (e.g., jewelry, musical instruments, toys).

Metal finishing operations are either captive shops or job shops. Captive shops perform finishing activities on the parts that they manufacture and/or that they subsequently use in downstream manufacturing. Job shops are separate entities that do not manufacture parts or use their products in other manufacturing applications. Job shops are a service industry that provides metal finishing for manufacturers.

In the United States, there are approximately 10,000 captive metal finishing operations and 3,500 job shops. These facilities are overwhelmingly located (80%) in highly industrialized regions of the northeast, midwest, and far west. Most of the shops are small, but a few large operations exist (the average shop employs 65 people, and the median facility employs just 35). Similarly, the average plant discharges 37,000 gpd of wastewater, and the median facility discharges only 14,000 gpd. Most plating facilities are reasonably new by industrial standards with the average and median facility age of 28 years.

With the exception of leading edge technology, relatively few technological differences exist between the metal finishing processes used by different countries. This is due to the following factors: simplicity of conventional metal finishing technologies and the limited requirement for skilled labor; expansion of major chemical suppliers to a world-wide market; world-wide trade organizations and other forms of international cooperation; and open access to major universities and colleges where research is conducted.

Significant differences do exist in metal plating operations, however, depending on the level of economic development across nations, variations in demand for sophisticated plating applications, the availability of capital, and environmental law and regulatory constraints. Over the past 10 to 20 years, metal platers in developed countries have undergone a major technological shift from decorative finishes, such as nickel-chrome coatings on steel and zinc diecast parts, to specialty finishes and more processing of aerospace and electronic parts. Metal platers in less developed nations have not been forced to respond to these changes and have, as a result, experienced far fewer and less rapid technological advancements. Similarly, developed countries have stable or decreasing needs for unskilled labor due to automation; these trends have not occurred in less developed nations.

The scope and stringency of environmental regulations applicable to the metal plating industry are also increasing. Such changes have forced nearly all metal platers to increase investments in pollution control equipment, employee training, and waste treatment and disposal services. The level of these requirements and the ability of metal platers to respond to these increased standards is not uniform, however. In many countries, the struggle to comply with more stringent environmental requirements has been difficult due to the concurrent world-wide recession of the 1980's. In fact, some countries have witnessed the demise of 30 to 50 percent of their plating industry during the past decade. Even within developed countries, platers are faced with non-uniform requirements and enforcement.

1.2 Overview of Metal Plating Processes

Metal finishing comprises a broad range of processes that are practiced by most industries engaged in manufacturing operations using metal parts. Typically, metal finishing is performed on manufactured parts after they have been shaped, formed, forged, drilled, turned, wrought, cast, etc. A "finish" can be defined as any final operation applied to the surface of a metal article in order to alter its surface properties to achieve various goals. Metal finishing operations are intended to increase corrosion or abrasion resistance, alter appearance, serve as an improved base for the adhesion of other materials (e.g., other metals, paints, lacquers, oils), enhance frictional characteristics, add hardness, improve solderability, add specific electrical properties, or improve the utility of the product in some other way. Common metal finishes include paint, lacquer, ceramic coatings, and electroplating.

Plating and surface treatment processes are typically batch operations, in which metal objects are dipped into and then removed from baths containing various reagents to achieve the desired surface condition. The processes involve moving the object being coated through a series of baths designed to produce the desired end product. These processes can be manual or highly automated operations, depending on the level of sophistication and modernization of the facility and the application.

Plating operations can generally be categorized as electroplating and electroless plating processes. Surface treatment includes chemical and electrochemical conversion, case hardening, metallic coating, and chemical coating. Most metal surface treatment and plating operations have three basic steps: surface cleaning or preparation, which involves the use of solvents, alkaline cleaners, acid cleaners, abrasive materials, and/or water; surface modification, which involves some change in surface properties, such as application of a metal layer or hardening; and rinsing or other workpiece finishing operations to produce the final product.

The following discussion briefly describes the major plating and surface treatment processes to provide a context for the more in-depth discussion of waste minimization and pollution prevention opportunities available to the industry.

1.2.1 Electroplating

Electroplating is achieved by passing an electrical current through a solution containing dissolved metal ions and the metal object to be plated. The metal object serves as the cathode in an electrochemical cell, attracting metal ions from the solution. Ferrous and non-ferrous metal objects are plated with a variety of metals, including aluminum, brass, bronze, cadmium, copper, chromium, iron, lead, nickel, tin, and zinc, as well as precious metals, such as gold, platinum, and silver. The process is regulated by controlling a variety of parameters, including the voltage and amperage, temperature, residence times, and the purity of bath solutions. Plating baths are almost always aqueous solutions; therefore, only those metals that can be reduced from aqueous solutions of their salts can be electrodeposited. The only major exception is aluminum, which can be plated from organic electrolytes.

The sequence of unit operations in an electroplating operation typically involves various cleaning steps, stripping of old plating or paint, electroplating steps, and rinsing between and after each of these operations. Electroless plating uses similar steps but involves the deposition of metal on a substrate without the use of external electrical energy.

1.2.2 Chemical and Electrochemical Conversion

Chemical and electrochemical conversion treatments deposit a protective and/or a decorative coating on a metal surface. In some instances, these processes can also be a preparatory step prior to painting. Chemical and electrochemical conversion processes include phosphating, chromating, anodizing, passivation, and metal coloring.

1.2.3 Case Hardening

Case hardening processes result in a hard surface, or case, over a metal core that remains relatively soft. The case is wear resistant and durable; the core remains strong and ductile. Case hardening methods include carburizing, carbonitriding, nitriding, microcasing, and hardening using localized heating and quenching.

1.2.4 Metallic Coatings

Metallic coatings provide a layer that changes the surface properties of the workpiece to those of the metal being applied. The workpiece becomes a composite material exhibiting properties generally not achievable by either material if used alone. The coatings provide a durable, corrosion-resistant layer, and the core material provides the load bearing capability. Metallic coatings include diffusion coatings, spraying techniques, cladding, vapor deposition, and vacuum coating. Because these processes do not involve the use of aqueous solutions, they may offer significant potential pollution prevention benefits over conventional electroplating operations in specific applications. As such, these techniques are discussed in greater detail in Section 3, Waste Minimization/ Pollution Prevention Techniques.

1.3 Waste Stream Characterization

The plating industry is somewhat unusual among manufacturing industries at present because the vast majority of the chemicals used end up as waste. The current inefficiency of material use is due to the inherent characteristics of the processes employed where parts are immersed into concentrated tanks of chemicals and are subsequently rinsed in rinse tanks that flow with fresh water. The resultant wastewater makes up the greatest volume of waste material from plating operations.

Wastewater is generated during rinsing operations. Rinsing is necessary to remove the thin film of concentrated chemicals (i.e., drag-out) that adheres to parts after their removal from process baths (e.g., plating solution). Wastewaters are usually treated on-site. This treatment generates a hazardous sludge that must be disposed of in an approved landfill or sent to a recovery site for metals reclamation. **Exhibit 1-1** presents an overview of chemical use and waste generation in the plating shop and a portion of their life cycle.

Residual metals in wastewaters discharged by plating shops to municipal sewer systems will be partially removed by the biological treatment process of the municipality (also generating a sludge) and the remainder will be discharged to a water body. Process baths are discharged periodically when they lose their effectiveness due to chemical depletion or contamination. Accidental discharges of these chemicals occur sometimes (e.g., when a tank is overfilled). These concentrated wastes are either treated on-site or are hauled to an off-site treatment or recovery facility.

With respect to air emissions, the greatest concerns with plating shops are solvents and chromium. Solvents are partly evaporated during degreasing operations. Contaminated liquid solvents are either recovered by distillation (on-site or off-site) or sent for disposal (incineration). Chromium is released to the air by plating and anodizing processes. Most shops do not have controls for organics; however, some larger plants use carbon adsorption units to remove hydrocarbons. Chromium emissions and other heavy metals are frequently controlled by the use of wet scrubbers. The discharge of these systems is sent to the wastewater treatment system and combined with other wastewaters for processing.

Plating also generates other miscellaneous sources of wastes, including floor wash waters, stormwater, and chemical packaging wastes. **Exhibit 1-2** identifies the major waste streams from typical metal plating operations, as well as the major waste constituents of concern from both regulatory and environmental risk perspectives.

1.4 Waste Minimization/Pollution Prevention Techniques

During the past 10 to 15 years, innovative members of the plating industry have made significant strides in developing and implementing preventative methods of pollution control. In some cases, waste minimization methods and technologies have been responsible for reducing waste volumes by up to 90 percent. Associated with the decrease in waste generation are a reduction in end-of-pipe equipment purchases, improvements in effluent compliance, improvements in product quality, and significant cost savings in raw materials.

In fact, metal plating and finishing operations represent some of the best and most classic applications of pollution prevention approaches. Numerous opportunities exist for source reduction ranging from complex technological advances to relatively simple and inexpensive operational changes. **Exhibit 1-3** presents waste minimization opportunities applicable to the metal plating industry in the context of the U.S. Environmental Protection Agency's (USEPA) waste management hierarchy (waste management via source reduction, recycling and reuse, and, as a last resort, environmentally sound treatment and disposal). It should be noted that many lower technology waste minimization options, including process recovery and reuse, improved operating procedures, and use of waste exchanges and off-site recovery options, represent significant opportunities for waste reduction often with relatively low investment requirements. Similarly, options such as product replacement (e.g., paints, plastics) may represent the ultimate pollution prevention option. Product replacement and similar approaches are largely driven by end users and consumer preferences and are not likely to be favored by the plating industry.

Exhibit 1-4 presents a more detailed identification of the specific waste reduction techniques that have documented applicability to metal plating processes and briefly describes the applications and limitations of each. All of these methods are described in detail in the body of the paper with discussions of the current use and applicability, limitations, and costs associated with purchasing, installing, and operating the various technologies.

1.5 Policy Approaches Promoting Pollution Prevention and Cleaner Production

In the United States and abroad, there has been a rapid expansion in the number and types of laws and policies focusing on pollution prevention and cleaner production. These laws and policies generally rely on planning; the creation of incentives; imposition of reporting requirements; and other indirect means of fostering waste reduction. In most countries, these policies work in tandem with traditional environmental regulations that create financial and liability-based incentives for industrial and manufacturing operations, including metal finishers, to reduce waste generation.

1.5.1 U.S. Policy Approaches

Given the substantial environmental regulatory framework that exists in the United States, the current approach appears to rely on creating both positive and negative incentives, as well as on developing the tools needed to foster waste reduction.

The positive incentives being promoted take the form of cost savings through improved efficiency,

Exhibit 1-1. Overview of Chemical Use and Waste Generation in a Plating Shop

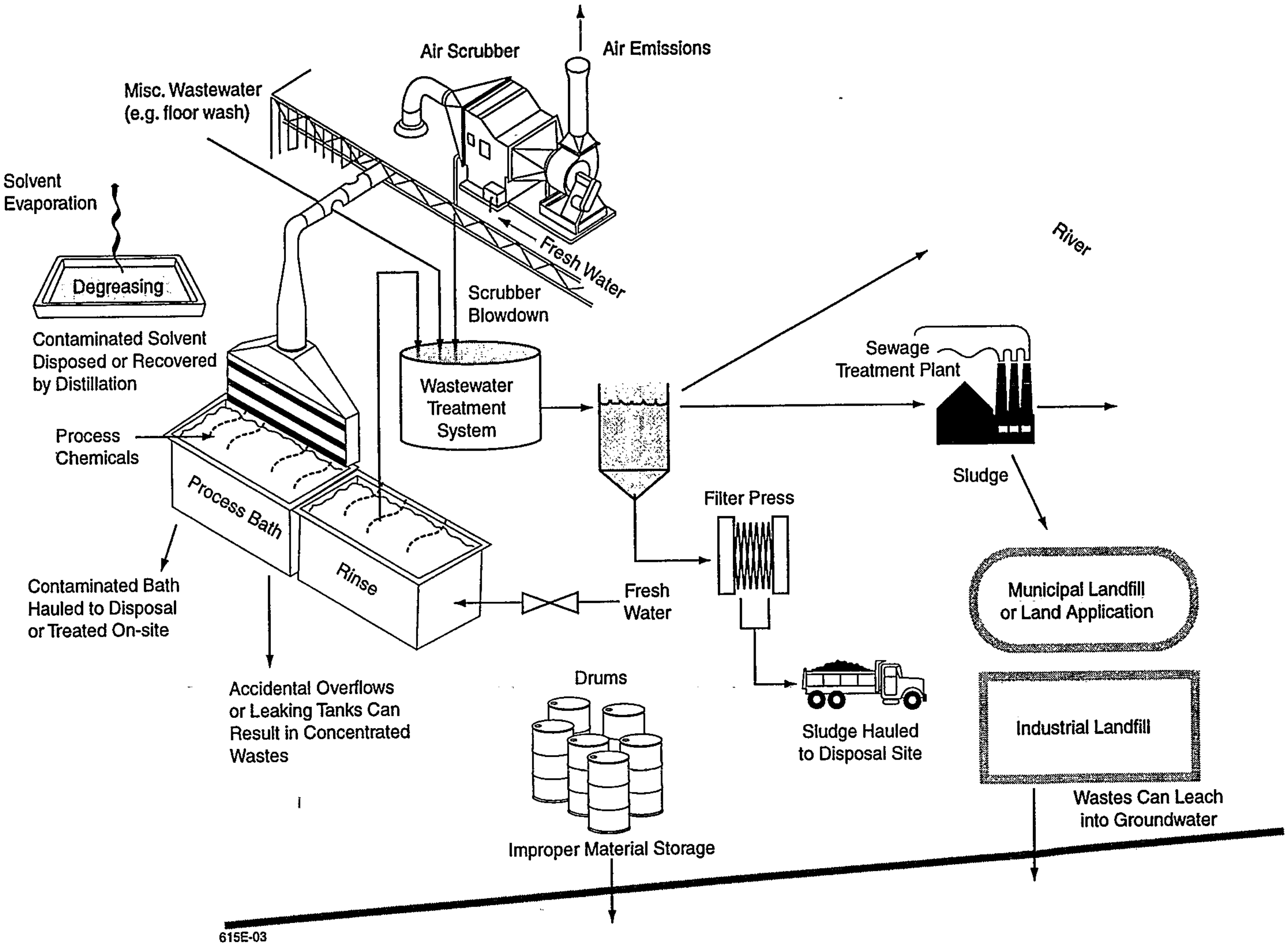


Exhibit 1-2. Major Metal Plating Wastes and Constituents

<u>Air Emissions</u>

Solvent releases from degreasing operations
Chromium

<u>Wastewaters</u>

Rinse Water
Spent Baths
Scrubber Blowdown
Cooling Water

<u>Solid and Hazardous Wastes</u>

Solvent Wastes
- Spent contaminated solvents
- Still bottoms from solvent recovery

Spent Process Solutions
- Alkaline cleaners
- Acid etching solutions
- Plating solutions

Wastewater Treatment Sludge

<u>Key Constituents</u>

Solvents
- 1,1,1-Trichloroethane
- Trichlorethylene
- Perchloroethylene
- Chlorofluorocarbons
- Methylene chloride
- Acetone
- Toluene
- Methyl Ethyl Ketone
- Methyl Isobutyl Ketone

Metals
- Cyanide
- Chromium
- Cadmium
- Nickel
- Aluminum
- Copper
- Iron
- Lead
- Tin
- Zinc

U.S. and International Waste Reduction Policy Approaches

- Direct regulation of materials used by or emissions produced by metal finishers
- Phase-out of harmful materials used by metal finishers
- Grant programs
- Information clearinghouses and technology transfer
- Reporting requirements
- Certification programs
- Creative enforcement programs
- Voluntary programs targeting specific harmful chemicals
- Research and development assistance
- Federal facility programs
- Tax/economic incentives
- Waste exchanges

reduced liability, improved competitiveness, and a positive public image. These benefits are being promoted through participation in voluntary programs, as well as through increased emphasis on more efficient production by individual companies and industry sectors. The waste reduction tools include new technologies, materials, and practices that often developed with the support of grants, technology transfer, or information exchange. Mechanisms such as the Toxics Release Inventory (TRI) also serve as tools for measuring progress in waste reduction, a necessary function if progress is to be quantified.

The negative incentives that are part of U.S. waste reduction policy include the traditional burdens of regulation: increased treatment and disposal costs and increased potential liability. These burdens force metal finishers and others to seriously consider waste reduction opportunities.

Within the United States, much of the waste reduction activity is occurring at the State level. States have been willing to be more direct in addressing pollution prevention—requiring industries to meet planning requirements and promoting pollution prevention through multi-media inspections and through creative permit requirements. Some States, such as Minnesota, Wisconsin, North Carolina, and Michigan, have developed workshops and publications focusing on pollution prevention within the metal finishing industry.

Another important area of activity in the United States is federal facilities. Federal facilities, which encompass many types of production processes, including metal finishing, are subject to recent Executive

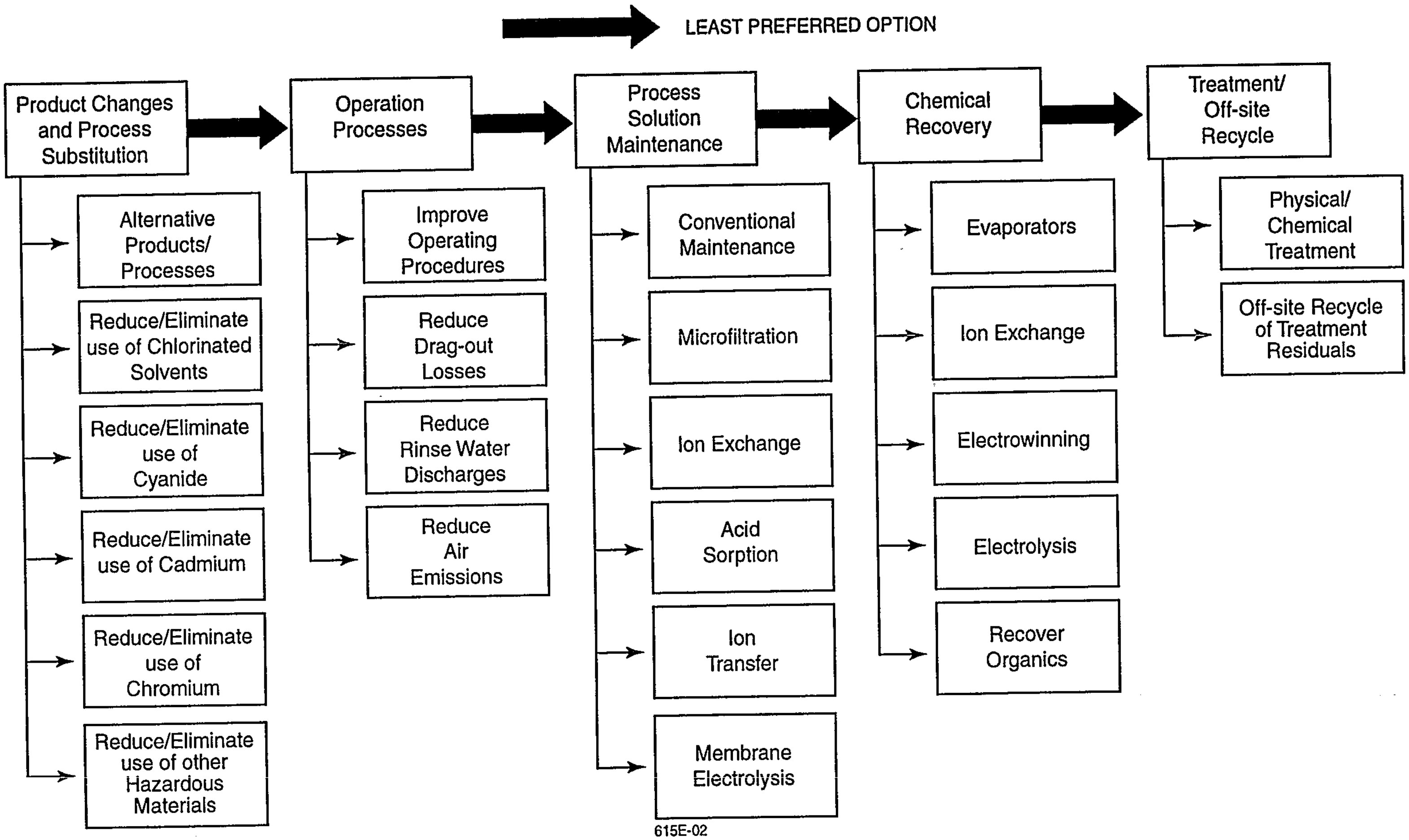
Exhibit 1-3. Waste Minimization Opportunities Available to the Metal Plating Industry

Category of Waste Minimization Options	Examples	Applications	Limitations
General Waste Reduction Practices	Improved operating procedures Drag-out reduction Rinse-water use reduction Air emissions reduction	Applicable to all conventional plating operations Should be considered standard operating procedures and/or good design Cost benefits typically outweigh any necessary expenditures	Existing facilities may be able to accommodate changes due to process configuration, space constraints, etc.
Alternative Processes	Thermal Spray Coatings • Combustion torch • Electric arc • Plasma sprays Vapor Deposition • Ion plating • Ion implantation • Sputtering and sputter deposition • Laser surface alloying Chemical Vapor Deposition	Primarily repair operations although they are now being incorporated into original manufacturing Primarily high-technology applications that can bear additional costs Expected to improve product quality and life	Technologies in varying states of development; commercial availability may be limited in certain cases Expense often limits application to expensive parts (e.g., aerospace, electronics, military) May require improved process controls, employee training, and automation
Process Substitution	Product changes Input material changes • Chlorinated solvents • Cyanide • Cadmium • Chromium	Applicable to most conventional plating operations Captive shops/manufacturers may be able to explore product changes	Job shops may have little control or input in decisions Product changes need to be evaluated in terms of consumer preferences Product specifications may eliminate consideration of some process substitutes

Exhibit 1-3. Waste Minimization Opportunities Available to the Metal Plating Industry (Continued)

Category of Waste Minimization Options	Examples	Applications	Limitations
Process Solution Maintenance	Conventional maintenance methods Advanced maintenance methods • Microfiltration • Ion exchange • Acid sorption • Ion transfer • Membrane electrolysis • Process monitoring and control	Conventional methods applicable to all plating operations	Advanced methods may require significant changes in process design, operation, and chemistry Application limited for some plating process/technology combinations (e.g., microfiltration not applicable to copper or aluminum)
Chemical Recovery Technologies	Evaporation Ion exchange Electrowinning Electrodialysis Reverse osmosis	Requires significant engineering, planning, and characterization of process chemistry	Costs are highly variable for advanced methods Application must be carefully tailored to process chemistry
Off-Site Metals Recovery	Filtration Ion exchange Electrowinning Electrolytic recovery	Metal-bearing wastewater treatment sludge	Waste materials must be acceptable to recyclers

Exhibit 1-4. Waste Minimization/Pollution Prevention Methods and Technologies



Orders regarding ozone protection, TRI participation, and overall environmental compliance. Combined, these requirements are prompting such facilities to embrace pollution prevention and cleaner production principles.

Although no single U.S. waste reduction policy appears to be more effective than any other, several are worth highlighting. Foremost may be the TRI, which is not literally a pollution prevention statute but a public right-to-know (i.e., reporting) law. By quantifying and publicizing the toxic releases emitted by industry, the TRI has motivated industry to reduce such releases. The TRI has also become a major mechanism for measuring progress in waste reduction programs. It must be noted that TRI data only measure releases of toxic constituents to the environment and using these data as a tool to measure waste reduction is subject to important limitations (e.g., limits on applicability, changes in reporting requirements, availability of release data to reporting facilities).

A second noteworthy program is USEPA's 33/50 program, a voluntary program that seeks the reduction of 17 target toxics, including several used and released by the metal finishing industry. Preliminary results indicate that over a 33-percent reduction has been achieved in the metal fabricating sub-category from the 1988 baseline to 1992. **Exhibit 1-5** provides a summary and overview of U.S. policies and options.

1.5.2 International Policy

An Overview of Individual Country Programs

Most of the policy approaches adopted by various Organisation for Economic Cooperation and Development (OECD) countries are similar to those used in the United States, combining regulation, incentives, and information transfer. Typically, these policies are broad in scope, applying to all industries. For example, the German federal air pollution law has general provisions that require minimization of toxic air emissions, which directly impact the metal finishing industry. Another example is the recently enacted United Kingdom (U.K.) Integrated Pollution Control (IPC) statute that applies to the release of pollutants to air, water, and land from certain processes. The U.K. metal finishing industry was directly affected due to certain prescribed activities, including industrial cleaning and finishing.

Exhibit 1-6 provides an overview of general international policy options but does not identify the application specific to the metal plating industry.

OECD countries are somewhat different from the United States with respect to the degree to which they work with their governments on different issues, including pollution prevention. Governments sponsor research, develop waste management plans, implement waste collection and management programs, and help develop waste-specific reduction programs. Governments also provide certain funding for waste reduction research. This close working relationship promotes communication and understanding, which often results in the government establishing acceptable waste reduction goals that achieve a high degree of voluntary compliance. It also recognizes that the expertise regarding source reduction ultimately resides in industry and establishes a framework capable of accessing this expertise. Of the OECD countries, Germany, Japan, and Denmark are prominent in fostering this type of public/private relationship.

The European Community

The European Community recently adopted a draft directive aimed at reducing and controlling pollution from industrial installations. The directive introduces a system of integrated pollution prevention and control (IPPC), which is similar to the integrated pollution control system now operating in the U.K. under the Environmental Protection Act of 1990. The distinguishing feature of these approaches is that they are multi-media in scope.

The IPPC requires that operators of industrial installations in specific categories with a high potential to cause pollution obtain a permit in order to operate. Permit applications must include a description of the proposed measures to prevent or minimize emissions from the installation and evidence that the installation meets protective emission limits. The directive covers the production and processing of metals, as well as installations using more than 200 kg/h of organic solvent. Smaller scale operations are generally excluded from the scope of the directive.

The Nordic Council

The Nordic Council, which was formed to promote cooperation among the parliaments and governments of Denmark, Iceland, Norway, Sweden, and Finland, met in March 1992 and developed the Nordic Action Programme on Cleaner Technologies. This program builds on the conclusions of the Brundtland Commission concerning the need to reduce energy consumption and to develop cleaner technologies. The program is divided into four areas: information exchange, substitution of toxic components and products that impede recycling, employment of administrative control measures to encourage the use of clean technologies, and education regarding clean technologies. The Council has set up an industry network to disseminate information on Nordic cleaner technologies, hosted industry-specific seminars, established a

Exhibit 1-5. Summary of U.S. Policies and Programs Relevant to Metal Finishing Industry

Policy Approach/ Mechanism	Application to Metal Finishing	Policy Implications
Direct Regulations		
Pollution Prevention Act	• Sets out a host of USEPA pollution prevention activities. • Establishes pollution prevention grant program. • Establishes a pollution prevention clearinghouse. • Requires annual source reduction and recycling report. • Requires a biennial Report to Congress. • Is applicable to all industries, including **metal finishing**.	• Institutionalizes pollution prevention within USEPA. • Creates incentives for States to pursue pollution prevention. • Promotes information transfer. • Starts to measure progress and identify key issues. • Promotes broad-based pollution prevention, including within the **metal finishing industry**.
Resource Conservation and Recovery Act (RCRA)	• Directly regulates several **metal finishing wastes** as hazardous waste. • Requires all hazardous waste generators, including **metal finishing**, to certify that they have a program in place to reduce the volume or quantity and toxicity of waste they manage.	• Rigorous regulatory scheme applicable to **metal finishing wastes** that are hazardous wastes creates strong financial and liability incentives to pursue source reduction.
Clean Water Act (CWA)	• Imposes technology-based, industry-specific effluent limits on pollutants that a facility is allowed to discharge into the Nation's waters; standards may recommend in-plant controls.	• Effluent limits raise cost of treatment and disposal and thereby create financial incentive for source reduction. • In-house controls provide process/procedural modifications that achieve waste reduction.
Clean Air Act (CAA)	• USEPA required to regulate 189 air toxics and has authority to require pollution prevention measures (installation of control equipment, process changes, the substitution of materials, changes to work practices, and operator training/certification). • Industries addressed include **metal finishers** and many others. • Requires phase-out of production and sale of chlorofluorocarbons (CFCs) and several other ozone-unfriendly chemicals; imposes controls on CFC-containing products. • New sources located in non-attainment areas must use most stringent controls and emissions offsets that compensate for residual emissions.	• Air toxic regulation increases the cost of generating numerous air emissions produced by metal finishers, increasing incentives for waste reduction. • Restrictions on CFCs limit some chemicals used by **metal finishers** and force use of environmentally friendlier alternatives, including aqueous and semi-aqueous degreasers. • Offsets may be achieved through pollution prevention.

Exhibit 1-5. Summary of U.S. Policies and Programs Relevant to Metal Finishing Industry (Continued)

Policy Approach/ Mechanism	Application to Metal Finishing	Policy Implications
Direct Regulations		
Emergency Planning and Community Right-to-Know	• Requires select industries to report environmental releases of specified toxic chemicals (TRI). • Applies to metal fabricating category and other industries that conduct **metal finishing.**	• Reporting requirements have created strong incentives to reduce waste generation and releases for all industries, including **metal finishing.** • Release data have spurred increased industry and public scrutiny of waste generation and manufacturing operations.
Executive Orders		
Executive Order 12843	• Requires federal agencies to implement Montreal Protocol and prompt the phase-out of ozone depleting substances, including chemicals used by the **metal finishing industry.**	• Requires the phase-out of ozone-depleting substances, such as 1,1,1-trichloroethane; forced U.S. metal plating operations to identify replacements, which include aqueous and semi-aqueous degreasers.
Enforcement Projects		
Supplemental Environmental Projects (SEPs)	• Allows USEPA enforcement actions to mitigate portions of penalties in exchange for respondent undertaking pollution prevention projects. • Reorients resources expended on penalties toward waste reduction across all regulated industries, including **metal finishing.**	• Provides incentive for industries subject to enforcement actions to undertake pollution prevention. • Potentially applicable to **metal finishing industry** due to its regulation under RCRA, CAA, and CWA.
USEPA 33/50	• Promotes ambitious targeted reduction of 17 key toxics. • Participants include members of **metal fabricating industry** and others conducting **metal finishing.**	• Promotes activity and commitment at level closest to the manufacturing process. • Preliminary results indicate that over 33-percent reduction achieved in metal fabricating sub-category.
Waste Reductions Evaluations at Federal Sites	• Department of Defense/USEPA initiative to evaluate pollution prevention at federal facilities and to promote technology transfer. Projects have included **metal plating** shops.	• Creates waste reduction culture within federal facilities. • Provides access to key pollution prevention information.
Common Sense Initiative (CSI)	• New USEPA effort designed to create pollution control and prevention strategies on an industry-by-industry basis. • Prevents cross-media transfer of pollutants.	• Goal is to achieve greater environmental protection at less cost by fostering government-industry cooperation in reviewing environmental regulations. • The metal finishing industry is one of six pilot projects.

Exhibit 1-5. Summary of U.S. Policies and Programs Relevant to Metal Finishing Industry (Continued)

Policy Approach/ Mechanism	Application to Metal Finishing	Policy Implications
Voluntary Programs		
Design for the Environment	• Promotes considerations of waste reduction and risk reduction in process and product design stage. Voluntary. • Uses clusters and cleaner technology substitute assessments.	• Creates interest in waste and risk reduction and recognition of specific steps that can be achieved in different industries. • USEPA has initiated joint **metal finishing Design for the Environment (DfE) projects,** focusing on developing energy, environment, and manufacturing assessment methodology.
Source Reduction Review Project	• Major integration of source reduction consideration within USEPA program offices. • Specific rulemakings targeted to encourage source reduction.	• Increases use of multi-media regulatory programs to promote source reduction where possible. • Emission limit on solvent use and a degreasing standard that would impact **metal finishers.**
Pollution Prevention Grants	• USEPA provides grants to States and funds joint federal agency projects.	• Promotes pollution prevention activity at State and federal level, some of which is targeted at promoting waste reduction in **metal finishing industries.**
Technology/Policy Transfer	• Host of USEPA and State activities focusing on promoting the development and dissemination of technical and non-technical pollution prevention information.	• Promotes education about the availability and benefits of waste reduction, as well as a network of resources that can be used to support specific projects, including those with **metal finishing industries.**

Exhibit 1-6. International Waste Minimization Programs

Country	Policy Approach	Scope	Implications
Australia	• Best Available Technology (BAT) Regulations (permitting)	• Municipal solid waste (MSW) and industrial firms with less than 250 people—some specific waste streams	• BAT regulations allow flexibility for emerging technologies/job shops escaping regulation
	• Economic—financial assistance	• Specific industries, including electroplating	• Financial assistance to induce industry implementation of waste minimization
Canada	• "Green Plan"	• Technical assistance for reduction of all waste by 50% by year 2000	• Strictly voluntary—results hard to predict
	• User charges and taxes	• MSW and industrial	• Involvement to reduce waste
	• Mandate federal government waste reduction	• Federal government—all waste	• Provides example
Denmark	• Statutory orders—packaging and recycling	• MSW	• Reduces solid waste
	• Permitting	• All industry	• Limits emissions to all media
	• Financial—taxes, duties, fees, grants, subsidiary	• All waste	• Encourages use of clean technologies
Finland	• Sustainable development statute and regulations	• Rational use of all national resources	• Mandatory reduction of industrial toxics
	• Permitting	• Large industrial firms	• Job shops escape regulation
	• Financial—surtax —Grants	• MSW, fuels, and waste oil	• No effect on metal finishing
		• Industry	• Implement innovative clean technology
Germany	• Statutory and regulations	• MSW and industrial	• Specific media regulations require clean technologies to eliminate emissions
	• Financial—disposal	• Costs for disposal of wastes, such as metal finishing	• Grant incentive for clean technology
	—Low-interest loan	• Industrial	• Covers cost up to 60% of investment in cleaner technologies
Italy	• Financial—priority benefits contributions	• Industry	• Encourages use of clean technologies
	• Regulations	• Industrial waste	• General not industry-specific
	• Education/demonstration/ information	• All waste	• Encourages waste minimization; not industry specific
Norway	• Statute & permits requirements—mandatory plans	• Industry	• Encourage waste minimization generally
	• Financial—subsidiaries	• Industries (also MSW)	• Financial incentive to invest in clean technologies

Exhibit 1-6. International Waste Minimization Programs (Continued)

Country	Policy Approach	Scope	Implications
U.K.	• Voluntary	• Industry	• Not measurable
	• Statutory regulations (IPC)	• Industrial emission standards	• Mandates clean technologies, especially metal finishing; prohibited clearing and finishing technology
	• Education/demonstration	• Disseminate case studies to industries	• Technical transfer to teach and encourage use of clean technology
	• Financial—grants	• Industrial (also MSW)	• Pays up to 50% of investment with clean technology
EC	• International directives and regulations	• Industrial in member countries	• Binding on member conditions, multi-media focus on industrial waste minimization
	• BAT permits	• Industrial	• Limit industrial emission
Nordic Council	• Regional Cooperative Voluntary—education	• Industrial networks, industrial seminars, newsletters	• Technical transfer to educate and hopefully encourage individual to voluntarily engage in cleaner technology

Nordic newsletter, and coordinated with the United Nations Environment Programme's cleaner production activities. In addition, work is proceeding on standardizing the methodology of life cycle assessment.

International Programs

Waste Exchanges

Waste exchanges provide a mechanism for reusing industrial waste by facilitating the transfer of waste materials from generators to entities interested in recycling or reusing the materials. Waste exchanges operate by maintaining a printed and/or electronic list of materials that generators or brokers have available. Depending on the operating practices of a given exchange, individuals or organizations interested in obtaining any of the listed materials either directly contact the lister to arrange a mutually agreeable transaction or contact the exchange. In almost every instance, waste exchanges do not take physical possession of the listed materials, nor do they warrant the condition or usability of any listed materials for a given purpose.

From 1972 to 1978, 12 waste exchanges were established in Europe to serve industrial generators and users (located in Austria, Denmark, Finland, France, Germany, Italy, Norway, Sweden, and Switzerland). Also during the 1970's, New Zealand, Australia, and Israel established waste exchanges. The first North American waste exchanges were established in 1973, a recent USEPA study identified more than 50 waste exchanges currently operating in North America.

Waste exchanges may represent a particularly powerful tool for the metal plating industry and metal plating wastes. As the data in **Exhibit 1-7** illustrates, many wastes typical of metal plating operations are routinely listed by North American exchanges (e.g., acids, alkalis, metal and metal sludges, solvents). Wastes such as spent acids, caustics, and solvents may be readily used for less exacting applications. Wastes containing valuable metals may be worthy of recovery or used as feeds to other processes. Similarly, metal platers may be able to use these waste streams as feedstocks if the purity of the materials is adequate.

Montreal Protocol

The Montreal Protocol has been adopted by more than 60 countries and took effect on January 1, 1989. The goal of the Protocol is to protect the ozone layer

Exhibit 1-7. Listings of Materials Wanted and Materials Available by Category from the National Material Exchange Network*
January 1, 1993, to May 19, 1993

Category	Materials Available		Materials Wanted	
	Number of Listings	Percentage of Total	Number of Listings	Percentage of Total
Acids	197	3%	50	3%
Alkali	181	2%	51	3%
Construction Material	45	1%	27	1%
Container and Pallet	366	5%	79	4%
Durable and Electronic	32	0%	45	2%
Glass	39	1%	15	1%
Laboratory Chemicals	2,350	32%	8	0%
Metal and Metal Sludge	367	5%	234	12%
Miscellaneous	677	9%	278	15%
Oil and Wax	234	3%	84	4%
Other Organic Chemicals	410	6%	82	4%
Other Inorganic Chemicals	508	7%	97	5%
Paint and Coating	96	1%	11	1%
Plastic and Rubber	826	11%	505	27%
Solvent	313	4%	67	4%
Textile and Leather	165	2%	70	4%
Wood and Paper	594	8%	196	10%
	7,400		1,899	

*These data do not include approximately 460 listings of available materials and 150 wanted listings from the Southeast Industrial Exchange and the Southern Waste Information Exchange based on recent catalog listings.

from man-made ozone depleting chemicals, some of which have traditionally been utilized in the metal finishing industry, such as the widely used cleaning solvent methyl chloroform (1,1,1-trichloroethane). In 1990, the parties to the Protocol agreed to accelerate the phaseout schedules for the substances already controlled by the Protocol. They also added phaseout requirements for other ozone depleting substances (ODS) including methyl chloroform, carbon tetrachloride, and chlorofluorocarbons (CFCs).

In November 1992, the Protocol was again amended in Copenhagen. The Copenhagen Amendments further accelerated various phaseout schedules and banned others. The amendment covers CFCs, halons, carbon tetrachloride, methyl chloroform, and hydrobromofluorocarbons. The changes, using 1986 as a baseline, required a 75-percent reduction of CFCs in 1994 and elimination by January 1, 1996. Halons were banned as of January 1, 1994, and carbon tetrachloride was banned as of January 1, 1995. Methyl chloroform faced a 50-percent reduction in 1994, an 85-percent reduction starting January 1, 1995, and a 100-percent elimination by January 1, 1996.

As a result of the Montreal Protocol, the metal finishing industry's widely used cleaning solvent, methyl chloroform (1,1,1-trichloroethane), came under attack, and the ambitious phaseout schedule has led many metal finishers to seek safer alternatives.

1.5.3 NAFTA

The recent passage of the North American Free Trade Agreement (NAFTA) highlights a challenging situation concerning how to reconcile international trade and environmental policy issues. NAFTA raises issues such as how trade agreements can be achieved in the context of heavy environmental regulation and how to harmonize international environmental and trade laws.

Unlike media-specific statutes of the United States, the environmental law of Mexico exists in a single broad statute. The environmental enforcement agency of Mexico, which is equivalent to the USEPA, is the

Secretaria de Desarrollo Urbano y Ecologia (SEDUE), formed in 1982. While Mexico's law is comprehensive in scope and sets reasonable ecological standards, compliance is minimal because enforcement is minimal. SEDUE estimates that 52 percent of the nation's maquiladoras have generated hazardous waste and few have obtained basic operating licenses. Mexico simply does not have the fiscal or human resources to adequately enforce its comprehensive environmental law.

While it is impossible to predict what impact NAFTA may ultimately have, its passage is likely to attract even more industrial production facilities (such as metal finishers) to Mexico and further compound the compliance problem. This issue is not unique to North America, but arises in any region with disparate environmental policies.

1.5.4 Future Trends

Based on the information reviewed in this section, the following observations can be made:

- Waste minimization programs that address metal plating operations will increase in number due to the toxic chemicals managed by this industry.
- These programs will be split among voluntary and mandatory programs, with mandatory programs being less "command and control" and more incentive driven.
- The overall regulation of metal finishers will continue to increase in scope and stringency, creating greater incentives for legitimate operators to pursue waste reduction/cleaner technologies and driving noncompliant operations to regions of minimal regulation or lax enforcement.
- International waste minimization currently focuses more on industrial and solid waste than does U.S. waste minimization.
- Small metal finishing operations appear to have special needs as they are forced to decide whether to pay the increasing cost of compliance, reduce waste generation, or become fugitive operations.

1.5.5 Sustainable Development

According to the United Nations World Commission on Environment and Development, the term "sustainable development" refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs. While the precise definition of the term is still the object of considerable international debate, consensus exists on several fundamental issues. Sustainable development requires a long-term perspective for planning and policy development; dictates actions that build on and reinforce the interdependence of our economy and our environment; and calls for new integrative approaches to achieve economic, social, and environmental objectives.

Sustainable development has emerged in recent years as a focal point for policy makers concerning the long-term economic and environmental outlook. The level of concern about sustainable development was made evident in 1992 at a United Nations Conference on Environment and Development. Representatives from 180 countries gathered at this conference to promote sustainable and environmentally sound development.

Many of the past and present USEPA programs have utilized tenets of sustainable development. USEPA, however, has not employed the concept as an overall policy framework or programmatic objective until very recently. The limited use of sustainable development concepts in USEPA policies is, in part, due to a lack of these concepts in its statutory mandates. It is generally agreed that statistically and scientifically credible environmental data and information are needed to measure progress toward environmental goals and sustainable development.

USEPA is implementing a program to gather and provide statistical information about the status and trends in the Nation's ecological systems. USEPA's Environmental Monitoring and Assessment Program is the first statistically based monitoring program to assess ecosystems on a national scale. The program is designed to advance the scientific knowledge of ecosystems and how these ecosystems are changing and responding to human activities.

1.6 Implications and Evaluation of Policies

To understand the impacts of current policies on the metal finishing industry, several points need to be understood. Cleaner technologies and products already exist in the metal finishing industry as a result of extensive government and trade association cooperation on product and process technology development and technology transfer, as well as military research and development. The metal finishing industry is very diverse in terms of processes (e.g., electroplating, plating, polishing, anodizing, and coloring) and size of operations within the industry. As a result, metal finishers can be categorized into firms that:

- Are in compliance with environmental requirements and proactive in improving environmental performance
- Seek to comply with applicable environmental regulation

- Are older and outdated and would close except for cleanup liability
- Are constantly out of compliance (i.e., renegade firms).

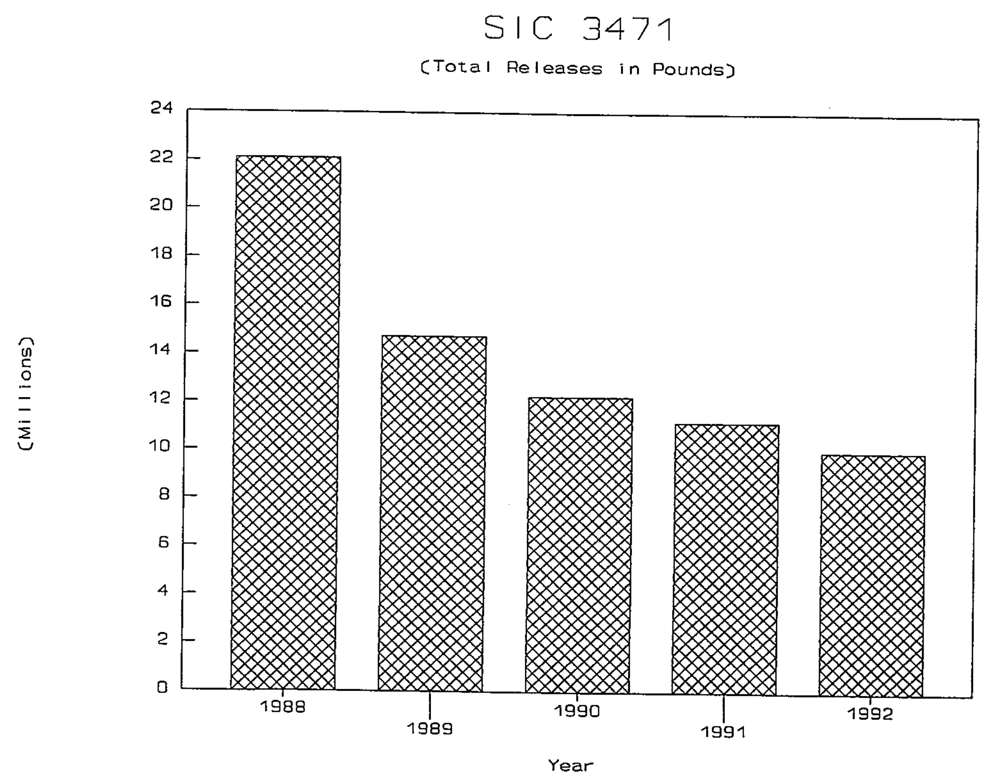
The differences among these groups are important in assessing pollution prevention policy, since the impact of different policies varies depending on which group is being targeted.

As discussed previously, numerous waste minimization policy initiatives are currently being pursued at all levels of government in most major industrialized countries. Many of these waste minimization initiatives affect the metal plating industry, although most are much broader in scope. In examining the effectiveness of these policies, several points should be noted. First, waste minimization policies are relatively new and it is difficult to assess the effects of programs that have only existed for a brief period. Second, given the broad array of policies and the lack of precise mechanisms for measuring their effectiveness, quantitative evaluation is not possible. Rather, it appears much more likely that the results that have been observed are the result of a combination of policy approaches (i.e., regulation of emissions combined with technology transfer, voluntary programs, and the existence of a mechanism for measuring success, such as the TRI). Despite these concerns, however, some preliminary assessment can be performed.

Within the United States, the most broadly used indicator of toxics loading to the environment is the TRI. The TRI measures releases to the environment of specific chemicals from specific industries (designated by Standard Industrial Classification [SIC] codes). According to TRI data for SIC 3471 (Electroplating) from 1988 to 1992, releases of TRI chemicals decreased 55 percent, from more than 22 million pounds to less than 10 million pounds released annually. This decrease is illustrated in **Exhibit 1-8**.

The TRI data provide some insight into how these reductions are being achieved. As part of the TRI reporting form, facilities are asked to indicate which, if any, waste reduction techniques they have used during the reporting period. The most common pollution prevention methods identified for SIC 3471 include the following:

Exhibit 1-8. TRI Release Data for SIC 3471 (1988 – 1992)



- Improved maintenance, scheduling, recordkeeping, or procedures
- Substituted raw materials
- Instituted recirculation within a process
- Changed to aqueous cleaners from solvents of other materials
- Implemented other changes in operating practices
- Made other process modifications.

These pollution prevention activities were identified through internal pollution prevention opportunity audits and vendor assistance, as well as through numerous other means.

Generally, the TRI data indicate that the more progressive portion of the metals fabricating industry has substantially reduced its releases over a relatively short period of time. Hence, some combination of waste minimization policies (e.g., regulation and incentives) is working for the proactive sector of the industry. As direct regulation of the metal plating industry or chemicals used by this industry increases, the incentive to achieve additional waste reductions will also increase. For marginal operations, policy approaches may need to link stringent enforcement or streamlined regulatory requirements with waste reduction opportunities to facilitate more environmentally sound behavior.

Barriers to pollution prevention in the metals finishing industry include regulatory and institutional barriers, such as inconsistency in existing regulatory requirements and enforcement actions (particularly given the significant environmental liabilities and clean-up costs some firms face if they discontinue operations); economical and financial barriers, such as the lack of the personnel and financial resources to look beyond baseline compliance; and technological barriers, such as a lack of access to newer, cost-effective, cleaner technology. In addition, industrial managers often do not appreciate the financial and other benefits associated with waste minimization and face significant psychological barriers when shifting to unknown but cleaner technologies. All of these barriers limit the use of pollution prevention in the metals finishing industry.

1.7 Technical Report Organization

The paper consists of the following five technical sections and five technical appendices:

- Section 2 – Waste Stream Characterization
- Section 3 – Waste Minimization/Pollution Prevention Techniques
- Section 4 – Examples of Waste Minimization/ Pollution Prevention Techniques
- Section 5 – Tools for Evaluating Pollution Prevention Opportunities
- Appendix A – International Policy Approaches to Encourage and Implement Pollution Prevention/ Cleaner Production
- Appendix B – Implications and Evaluation of Policies
- Appendix C – U.S. Federal and State Pollution Prevention Policy/Plans
- Appendix D – Pollution Prevention Contacts

2.0 WASTE STREAM CHARACTERIZATION

As with any complex industrial activity, metal plating processes result in a variety of wastes and environmental releases. This section identifies and describes major wastes and releases from typical plating facilities, discusses waste generation mechanisms, provides waste composition and quantities to the extent available, and describes typical waste recovery, treatment, and disposal options. The remainder of this section is organized to first discuss the life-cycle for plating wastes. Waste characterizations are then provided for three broad categories of wastes: (1) air emissions, (2) wastewater, and (3) solid and hazardous wastes. The section concludes with a brief discussion identifying the key stakeholders in waste generation activities.

2.1 Life Cycle for Wastes from Metal Plating Operations

Wastes from plating operations are generated by normal production activities as well as by accident. Accidental discharges can have highly acute impacts due to the concentrated nature of the hazardous materials in use, while normal processing wastes present more of a chronic problem due to the controlled and/or continuous nature of their discharge. **Exhibit 2-1** presents an overview of chemical use and waste generation in the plating shop and a portion of their life cycle.

Wastewater is primarily generated during rinsing operations to remove the thin film of concentrated chemicals (drag-out) that adhere to parts after they are removed from process baths. Wastewaters are usually treated on-site and discharged to municipal sewer systems rather than directly to water bodies. The on-site treatment of wastewater generates a hazardous sludge that must be disposed of in an approved landfill or sent to a recovery site for metals reclamation.

Residual metals discharged by plating shops to municipal sewer systems will be partially removed by the biological treatment process of the municipality and the remainder will be discharged to a water body. A high concentration of metals, such as cadmium may limit municipalities disposal options for their biological treatment of sludge. Some local governments impose strict limits on the effluent discharges from plating shops in order to meet their discharge and sludge disposal restrictions, which can be set at 10 to 20 percent of federal limits.

Process baths can be periodically discharged when they lose their effectiveness due to chemical depletion or contamination. Accidental discharges of these chemicals occur, for example, when a tank is overfilled. These concentrated wastes are either treated on-site or are hauled to an off-site treatment or recovery facility. On-site treatment of concentrated wastes is not always possible because they can upset treatment processes designed mainly for dilute wastewaters. Also, some spent cleaning solutions contain chelating compounds that prevent the complete precipitation of heavy metals during treatment.

With respect to air emissions, the greatest concerns with plating shops are solvents and chromium. Solvents are partly evaporated during degreasing operations. Chromium is released to the air by plating and anodizing processes.

Other miscellaneous sources of wastes from plating include floor wash waters, stormwater, and chemical packaging wastes.

2.2 Air Emissions

2.2.1 Waste Stream Identification

The primary air emissions problems for plating operations are associated with the use of chlorinated solvents and chromium. These are the only materials for which U.S. regulations or proposed regulations exist at this time.

Solvents

A number of solvents are used for metal cleaning, the choice of which depends on the application, costs, and preference of the user. Examples of solvents that are commonly used for this purpose include 1,1,1-trichloroethane (TCA), trichloroethylene (TCE), tetrachloroethylene (or perchloroethylene [PERC]), trichlorotrifluoroethane, acetone, toluene, methyl ethyl ketone, methyl isobutyl ketone, and methylene chloride.

Chromium

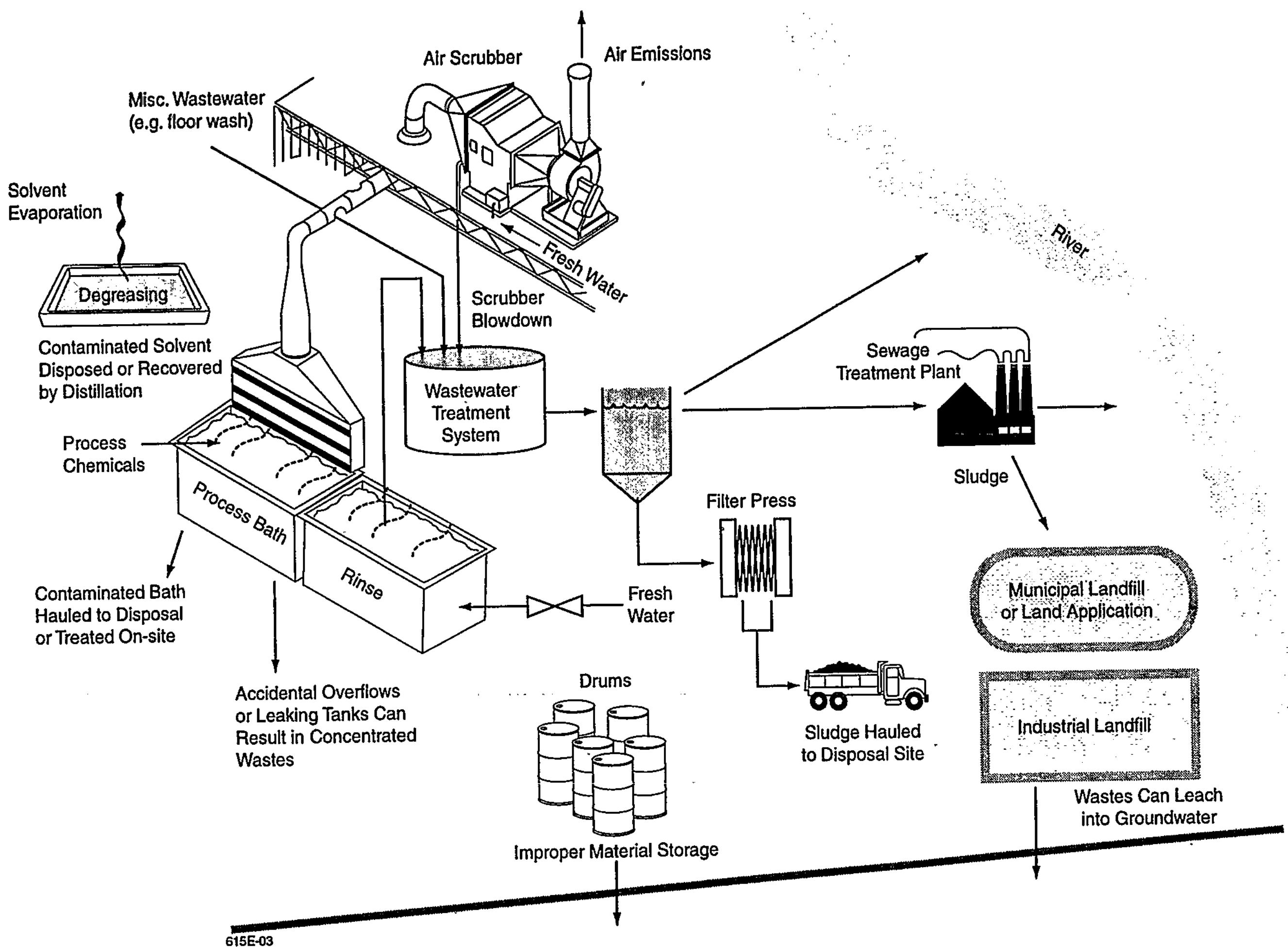
Since 1984, the U.S. Environmental Protection Agency (USEPA) has been investigating chromium electroplating operations as a source of chromium air emissions. Hard and decorative chrome plating and chromic acid anodizing are operated at elevated temperatures and a dc current is applied. These operating conditions result in the release of hexavalent chromium mist.

2.2.2 Waste Generation Mechanisms

Solvents

Chlorinated solvents are evaporated during degreasing operations. Vapor degreasing is performed

Exhibit 2-1. Overview of Chemical Use and Waste Generation in a Plating Shop



in a tank with a heated solvent reservoir at the bottom and cooling zone near the top. Sufficient heat is applied to boil the solvent to generate hot solvent vapor. The hot vapor fills the tank but is prevented from escaping by the upper cooling zone, which condenses the vapor and the resulting liquid solvent returns to the reservoir. During operation, parts are introduced to the vapor zone. Solvent condenses on the parts and dissolves the soils. The part eventually reaches the temperature of the solvent vapor and the condensing action stops. The part is then removed from the degreaser in a clean and dry condition. Solvent can be released to the air due to poor vapor degreaser design or operating practices. Examples of poor design include inadequate cooling zone and inadequate freeboard. Examples of poor operating practices include lowering or raising the parts too quickly.

When the cleaning ability of the solvent is diminished or becomes contaminated, the solvent must be discarded/replaced or purified, on-site. Most spent solvent is recovered at a solvent recycling facility. On-site purification and off-site recycling operations use solvent distillation equipment to separate the solvent from its contaminants. When this is done, the contaminants are concentrated into "still bottoms" and the solvent is returned to service. Some vapor losses may occur during distillation, depending mainly on the design characteristics and operating procedures employed.

Solvents are also used in a "cold" form (usually slightly above room temperature) for degreasing. This is usually performed in tanks by immersing the parts into the solvent and/or by spraying. Solvents used for this purpose include those used in vapor degreasers plus aliphatic petroleums (e.g., kerosene and mineral spirits) and alcohols. Ultrasonics or mechanical agitation are sometimes used with cold cleaning to improve soil removal mechanisms. The rate of solvent emissions from cold cleaning depends mostly on the type of solvent employed, the temperature of the process, and the application method (e.g., spraying will increase evaporative losses).

With hand wiping, a small amount of solvent is placed onto a rag or directly onto the part and the surface of the part is wiped clean. The thin film of solvent on the part evaporates into the workplace. Most solvents used for vapor degreasing and cold cleaning are also used in hand wiping.

When open top containers are used to immerse parts or to dispense solvent for hand-wiping operations, significant solvent losses to the atmosphere and workplace can occur.

Chromium

During the operation of chrome plating processes, chromic acid is heated and a dc current is passed through the solutions. The electrolytic process evolves hydrogen and oxygen gases that bubble to the surface of the solution and are released to the air above the bath. This results in the formation of a humid chromic mist or aerosol. Due to health concerns for operators of these processes, forced air ventilation must be used. The chromium mist is therefore pulled into an air exhaust system. Wet air scrubber systems and mesh pad mist eliminators can be used to remove the bulk of the chromium from the air stream prior to exhausting it to the atmosphere.

2.2.3 Waste Stream Quantities and Composition

Solvents

A 1994 survey of U.S. plating shops (mostly job shops) indicated that approximately 27 percent of the shops use chlorinated solvent for degreasing, most notably 1,1,1-TCA, TCE, PERC, chlorofluorocarbons (CFCs), and methylene chloride. The typical plating shop (as defined by 40 CFR 433.11(c)) purchases 16,000 lbs/yr of solvent for degreasing operations. This quantity of solvent is either evaporated during use or contaminated and sent off-site for recovery or disposal. The percentage of solvent lost to air emissions is not known.

Chromium

There are an estimated 9,700 chromium electroplating operations in the United States. These operations emit about 140.7 Mg/yr (175 tons/yr) of hexavalent chromium per year, with approximately 80 percent generated by hard chrome plating. Individual plating processes generate approximately 0.0094 kg Cr^{+3} trivalent chromium and 0.00024 kg hexavalent chromium (Cr^{+6}) per kg of chromic acid (CrO_3) used, respectively, for hard and decorative chrome plating.

2.2.4 Pollution Control and Treatment Methods

Solvents

Solvent emissions are presently controlled by management practices and carbon adsorption treatment systems. The proposed National Emissions Standards for Hazardous Air Pollutants (NESHAP), however, rely only on source-reduction methods and discourages the use of end-of-pipe or other waste treatment technologies, such as carbon adsorption units. The control equipment combinations proposed in the NESHAP are given in **Exhibit 2-2**.

Exhibit 2-2. Control Equipment Combinations and Idling Limits

	Control Equipment Combination Options[1]	Alternative Idling Limit kg/hr
Batch Vapor[2] (≤1.21 sq. meters)	1. FBR = 1, FRD, RRD 2. FBR = 1, BPC, RRD 3. BPC, FRD, RRD 4. CVR, FRD, RRD	0.15
Batch Vapor (>1.2 sq. meters)	1. BPC, FRD, RRD 2. BPC, DWL, RRD 3. DWL, FRD, RRD 4. BPC, FRD, RRD 5. BPC, RRD, SHV 6. FBR = 1, RRD, SHV 7. DWL, RRD, SHV	0.15
In-line existing[3]	FBR = 1	0.10
In-line new[3]	SHV, FRD	0.10
Batch Cold	CVR, water layer	N/A

[1]FBR - freeboard ratio, FRD - freeboard refrigeration device, RRD - reduced room draft, BPC - biparting cover, CVR - manual cover, DWL - dwell, SHV - superheated vapor
[2]New and existing equipment
[3]Vapor and cold cleaning

One source estimates that uncontrolled open-top vapor degreaser can release as much as 0.3 lbs/hr per square foot of degreaser opening. A summary of the effectiveness of emission control techniques on open-top degreasers is shown in **Exhibit 2-3**. With the controls listed in Exhibit 2-3 installed, a degreaser can reduce emissions up to 0.05 lbs/hr per square foot of degreaser opening. In a typical degreaser running at 4,000 hours per year, 1,800 lbs of solvent would be released compared to 10,800 lbs uncontrolled.

Chromium

The most common methods to reduce chromium emissions include (1) addition of chemical fume suppressants, wetting agents (reduces surface tension), and/or foam blankets to the bath to inhibit misting; (2) packed-bed scrubbers; (3) chevron mist eliminators; and (4) mesh pad mist eliminators. Some hard chrome plating processes can be replaced by metal sprays, nickel alloy plating, or other processes. Decorative chromium performed using hexavalent chromium can be converted to trivalent chromium. Chromic acid anodizing can be replaced by sulfuric/boric acid anodizing. Of the various technologies available for reducing chromium emissions, the mesh pad mist eliminator is the most effective. Also, due to the design of these devices, the chromic acid that is removed from the airstream can be returned to the plating or anodizing bath. The mist eliminator removes chromic acid from the airstream by slowing the velocity of the air and causing the entrained chromic acid droplets to impinge onto fiber pads. The pads are periodically washed with a small volume of water, and the chromium-rich solution is returned to the bath.

Exhibit 2-3. Effectiveness of Emission Control Techniques on Open-Top Degreasers

Device	Reduction in Solvent Emissions
Lid/sliding cover	38% - 50%
Above freezing chiller	18% - 50%
Below freezing chiller	11% - 58%
Refrigerated primary condenser	18% - 50%
Increased freeboard ratio (0.5 to 1.0)	25% - 39%
Controlled hoist speeds (10 fpm or less)	25% - 30%
Lip exhaust/reduced room drafts	42% - 54%
Enclosed design	42% - 67%
Carbon adsorption retrofit	40% - 90%

2.3 Wastewater

2.3.1 *Waste Stream Identification*

The primary use of water in a metal finishing shop is rinsing to dilute and wash away the chemical film of drag-out found on parts, racks, etc., after processing in a chemical bath. Other sources of wastewater, which include scrubber blowdown, cooling water, and spent baths, make up only about 10 to 20 percent of the flow from a typical plating shop.

2.3.2 *Waste Generation Mechanisms*

During processing, parts are hung on racks or hooks or placed into barrels and then dipped into various tanks using a prescribed sequence. Each plating process typically consists of alkaline cleaning, acid etching, and finishing. Rinsing is performed between each process step to remove drag-out. When a sufficient volume of rinse water is used to perform these functions, "good rinsing" is achieved.

The required flow of rinse water for a shop is directly related to the quantity of drag-out generated. The greater the drag-out rate, the more rinse water is needed to maintain good rinsing criteria. Drag-out is in turn a function of numerous factors related mainly to the process type, shape of parts processed, production equipment, bath concentration, bath temperature, bath viscosity, part orientation, the rate of withdrawl from the process tank, and the length of drain time provided. Of these factors, the shape of the parts and the type of transport device employed for the parts (e.g., racks, baskets, barrels) usually exhibit the greatest influence on drag-out rates. **Exhibit 2-4** shows some drag-out rate estimations for various shaped parts.

2.3.3 *Waste Stream Quantities and Composition*

A recent survey of U.S. plating shops showed that the wastewater discharge rates from plating shops ranges from zero to more than one million gallons per day (gpd) (see **Exhibit 2-5**). Approximately 8 percent of the shops responding to the survey had achieved zero discharge and the median flow rate for all shops is 14,000 gpd. Companies with zero discharge are typically small plating operations and most only performed hard chrome plating. This particular process is the easiest to operate at zero discharge because drag-out recovery rinsing can be used effectively.

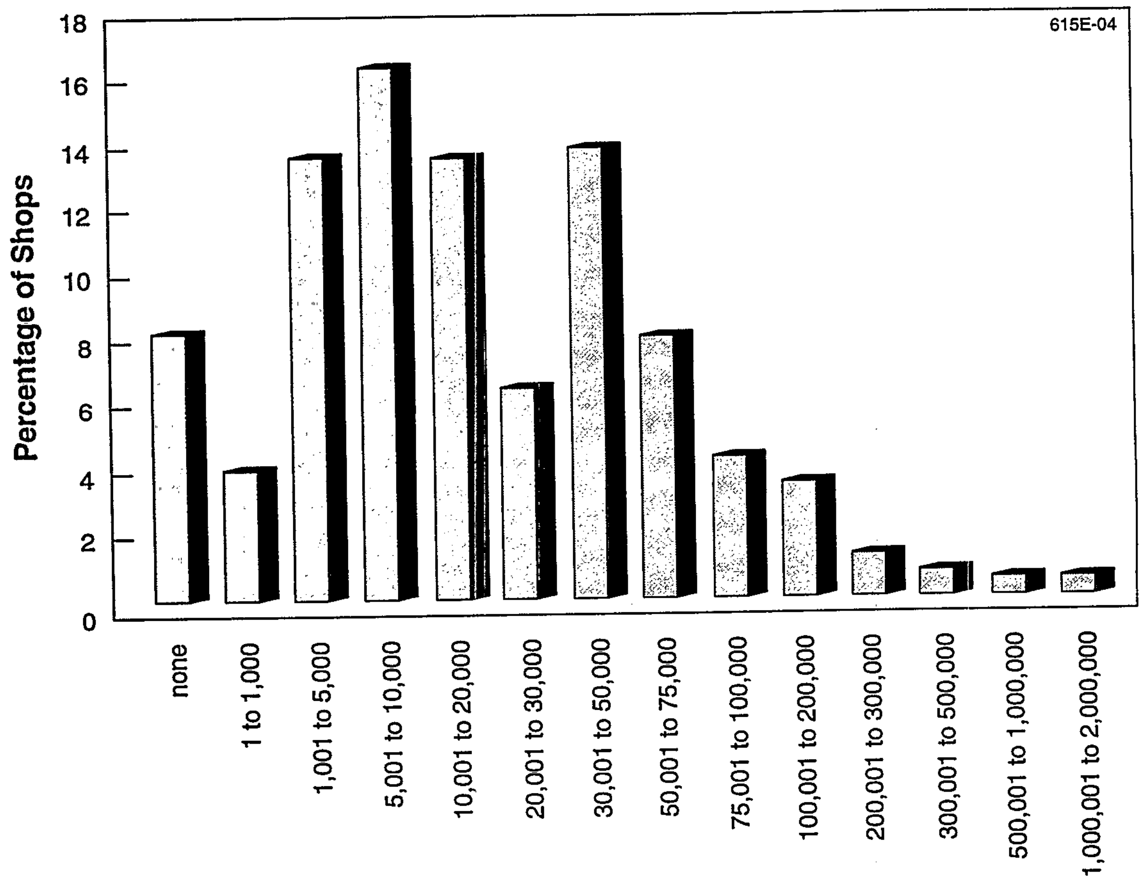
The composition of the wastewater will depend on the type of processes performed and the rinsing methods used. The concentration of the wastewater components will generally be higher for shops that employ pollution prevention due to the concentrating effect of reducing water use. Data from the industry survey show that the range of metals and cyanide concentrations in wastewaters are from less than 1 mg/l to more than 1,000 mg/l. However, the typical waste stream contains between 50 and 100 mg/l of metals and cyanide (when used).

Most plating shops segregate their wastewaters into three streams: cyanide bearing, chromium bearing, and miscellaneous acid and alkaline. Cyanide wastes cannot be mixed with acid wastes due to the potential formation of hydrogen cyanide. Cyanide and chromium wastes are treated by preliminary processes prior to metals precipitation.

Exhibit 2-4. Drag-Out Rate Estimates for Various Part Types

Nature of Work Drainage		Drag-Out Rate (gal/1,000 ft^2)
Vertical	Well drained	0.4
	Poorly drained	2.0
	Very poorly drained	4.0
Horizontal	Well drained	0.8
	Very poorly drained	10.0
Cup Shapes	Well drained	8.0
	Very poorly drained	24.0

Exhibit 2-5. Average Plating Discharge Rate of Survey Respondents (gallons per day)



2.3.4 Control and Treatment Methods

Rinse tank design and the rinsing configuration play an important role in determining the flow rate of wastewater from a shop. The key objectives with regard to optimal rinse tank design are to attain fast removal of drag-out from the part and complete dispersion of the drag-out throughout the rinse tank. When these objectives are achieved, the time necessary for rinsing is reduced and the concentration of contaminants on the part when it leaves the rinse tank are minimized for a given rinse water flow rate.

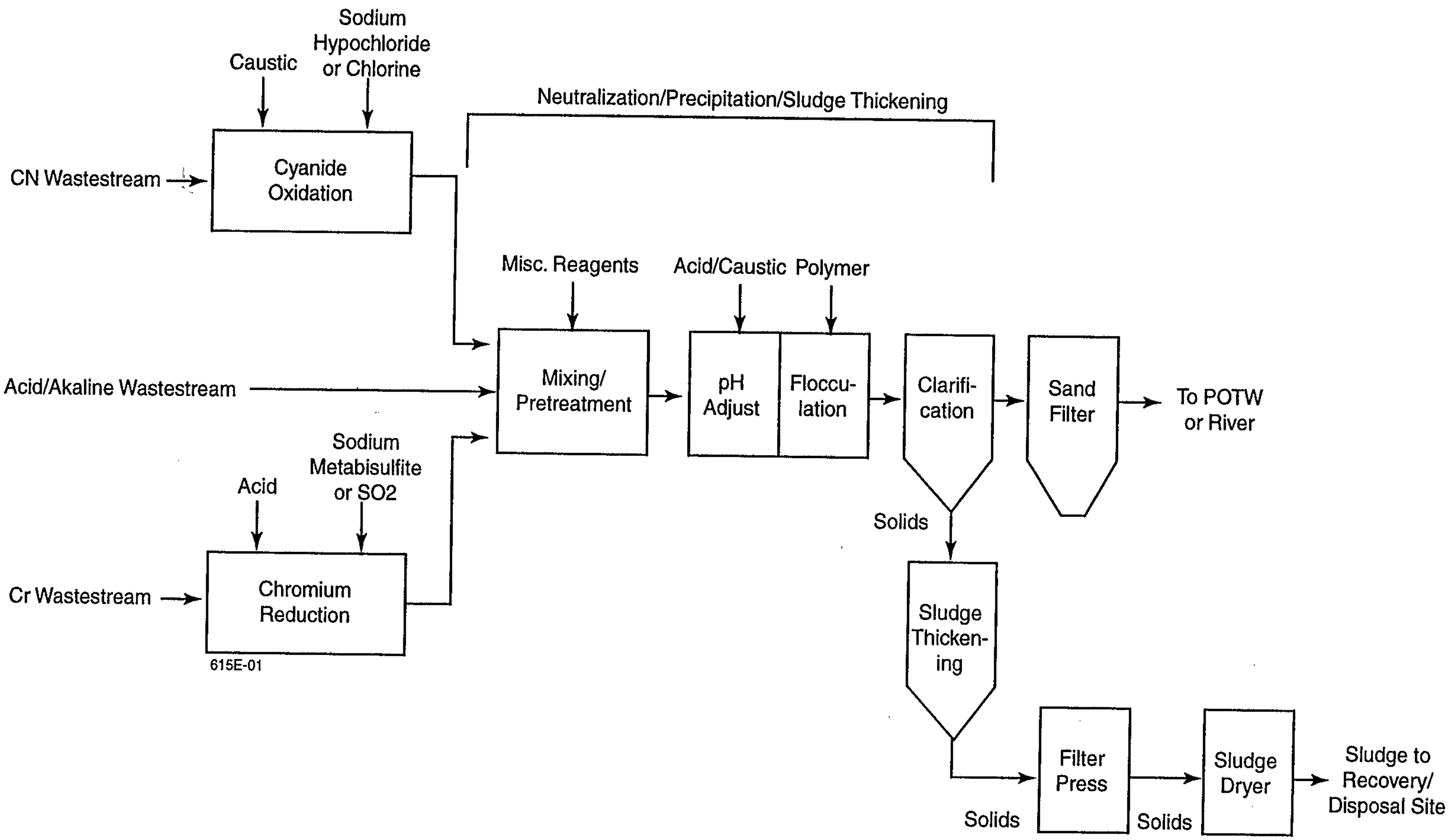
The use of single rinse tanks following each process tank is the most inefficient use of rinse water. Alternatively, multiple rinse tanks connected in series (i.e., counterflow rinse) can reduce the water needs of a given rinsing operation by orders of magnitude. Spray rinsing can also be used to reduce water use requirements. Other configurations that reduce water use include cascade, reactive, and dual purpose rinses.

Water use reduction can be achieved by coordinating water use and water use requirements. When water use and water use requirements are perfectly matched, the quantity of rinse water used for a given work load and tank arrangement is optimized. Most shops employ some form of rinse water control. The four most common methods are flow restrictors, manual control, conductivity controls, and timer rinse controls.

Most metal finishing shops employ physical/chemical treatment to process wastewaters prior to discharge. The conventional treatment system, shown in **Exhibit 2-6**, consists of preliminary treatment of cyanide and chromium bearing wastewaters followed by chemical precipitation, clarification, and filtration and solids dewatering.

Cyanide is most often destroyed using alkaline chlorination treatment. Hypochlorite (or other chlorine

Exhibit 2-6. Conventional End-Of-Pipe Treatment System



source) is added to the wastewater to oxidize cyanide to cyanate at a pH of 10 or higher. The pH is reduced to approximately 8.5 and additional hypochlorite is added. The cyanate is further oxidized to carbon dioxide and nitrogen. Alternatives to alkaline chlorination are peroxide or ozone oxidation, ferrous sulfate precipitation, and electrochemical and thermal oxidation. With the elimination of cyanide, the alkaline chlorination is not longer needed.

During chromium reduction, Cr^{+6} is reduced to trivalent chromium (Cr^{+3}). This process is performed since the hexavalent species cannot be precipitated from wastewater, whereas the trivalent species is readily removed. The most common method of chromium reduction involves the addition of sulfur dioxide gas or sodium metabisulfite at a pH between 2.0 and 3.0. Alternative methods that are used include sacrificial iron anode technology and ferrous sulfate reduction.

Following preliminary treatments, wastewaters are combined and treated for metals removal. The conventional method used in the plating industry is hydroxide precipitation. This is accomplished by adjusting the pH of the wastewater with an alkaline reagent to reduce the solubility of the dissolved metals and settling and removing the resultant metal hydroxide precipitants. Flocculating agents (usually organic polyelectrolytes) are added to the wastewater to cause precipitated metal hydroxides to agglomerate and settle more rapidly. The wastewater then enters a clarifier, where the precipitated solids settle. The solids are removed from the clarifier, thickened, and dewatered by mechanical and thermal means. Most frequently, recessed filter presses and sludge dryers are used to perform this function. The clarified wastewater can be further processed by filtration through a sand bed or multimedia filter before discharge to remove fine solids that do not settle in the clarifier. Alternative treatment methods to conventional precipitation/clarification include microfiltration, ion exchange, and evaporation.

2.4 Solid and Hazardous Waste

2.4.1 Waste Stream Identification

The primary hazardous wastes generated by metal finishing shops are solvent wastes, spent process solutions, and wastewater treatment sludge. Solvent wastes are usually in one of two forms: spent or contaminated solvents that are removed from degreasers or still bottoms from solvent recovery operations. Both of these wastes are hazardous and they are typically sent off-site for recovery or disposal. The most common spent process solutions are alkaline cleaners and acid etching solutions. These baths are discarded on a regular basis by many shops. Plating solutions (e.g., chrome and nickel plating baths) are typically rejuvenated and kept in permanent operation. Wastewater treatment sludge is usually the major solid or hazardous waste byproduct from plating. It is formed by the conventional hydroxide precipitation treatment process.

2.4.2 Waste Generation Mechanisms

Wastewater treatment sludge is generated during conventional treatment. The precipitated material removed from the clarifier is very wet or dilute in solids (approximately 97 to 99.5 percent water and only 3 to 0.5 percent solids). Due to the high cost for hauling and recovery/disposal, it is economically advantageous for shops to remove as much water from the sludge as possible. Therefore, shops typically employ several steps to progressively remove water from the sludge. The sludge is "thickened" to 2 to 5 percent, usually by gravity thickening (either a separate thickening tank or a zone within the clarifier). Mechanical dewatering is then used to increase the solids concentration of the thickened sludge to 10 to 60 percent solids. The most common mechanical device is the recessed plate filter press. Other equipment includes the older plate and frame filter press, centrifuges, and bag filters.

The solids content of the sludge dewatered on a filter press represents approximately a 20 to 1 volume reduction from the original sludge volume discharged from the clarifier. Additional dewatering can be accomplished with sludge dehydration equipment that can produce sludge with a dryness of 90 percent solids. This represents approximately a 4 to 1 volume reduction above that achieved by the filter press. Approximately 30 percent of U.S. shops have installed dehydration equipment, with more than 80 percent of these units being installed since 1988. Sludge dehydration is accomplished by exposing the sludge to a heat source that evaporates the excess water. Typically, there is some means of agitating the sludge, for example, with rotating blades, to improve the drying process. Units are available with either batch and continuous feed designs, and various heat sources can be used (electric, electric infrared, steam, and gas).

2.4.3 Waste Stream Quantities and Composition

The volume and composition of wastewater treatment sludge depends on the volume and composition of the wastewater treated, the nature and efficiency of the treatment process, the treatment reagents employed, and the dewatering process. The typical U.S. plater treats approximately 14,000 gpd of wastewater and generates 50,000 lbs/day of sludge with a solids content of 54 percent. However, large shops may generate more than 1 million lbs/day of sludge. **Exhibit 2-7** presents analytical data for sludges from various U.S. shops.

2.4.4 Pollution Control, Treatment, Recovery and Disposal Methods

In the United States, wastewater treatment sludge is generally disposed of in hazardous landfills or is sent to a metals recycling facility. Due to land disposal regulations, the sludge must be relatively stable (i.e., will not leach toxic metals) before land disposal. Some sludges must be processed before landfilling. The most common method of stabilizing sludges is solidification. With this process, cement or cement-like materials are added to the sludge to bind the hazardous metals and prevent leaching. An alternative to landfilling of wastewater treatment sludge is off-site metals recycling. According to a recent study, 31 percent of U.S. plating shops send sludge to a recycling facility. These sites are privately owned processing plants that separate and recover the metals from the sludges in forms that can be used as feed material for manufacturing processes. The most common end uses of the metal bearing materials include copper, cadmium, and zinc feed materials for primary metals manufacturing; chromium for stainless steel manufacturing; and wood treatment chemical reagents.

2.5 Key Players/Stakeholders Involved with Metal Plating Waste Generation and Management

Because of the variability in the size, application, processes, and nature of metal plating operations, numerous stakeholders may exist with both direct and indirect interests in the life cycle of wastes generated, as well as in any actions taken to reduce or eliminate these wastes. Obviously, stakeholders include those directly involved with metal plating operations. Indirect stakeholders include individuals and organizations involved both upstream and downstream in the life cycle of wastes and products derived from the metal plating activities. Policymakers and regulators responsible for protecting human health and the environment, as well as those with oversight responsibility for domestic and international commerce, also can represent key players in the development and implementation of policies aimed to force technology and operational changes within these industrial sectors. **Exhibit 2-8** identifies potential stakeholders and describes their involvement.

Exhibit 2-7. Analytical Data for F006 Sludges Provided by Respondents to the Users Survey

Parameters	PS018	PS043	PS061	PS062	PS106*	PS111	PS142*	PS207	PS212	PS243	PS253	PS264	PS268
% Solids	98.0%	–	32.0%	47.0%	58.3%	31.8%	71.8%	52.0%	38.0%	88.0%	50.0%	54.0%	47.3%
Aluminum	1,057	–	841	6,032	2,600	3,865	3,800	10,862	35,447	243	1,957	6,272	5,900
Antimony	278	–	63	264	–	113	–	164	406	572	47.0	1,030	–
Arsenic	≤26	–	5.0	2.4	<1,000	54.0	<200	197.0	256.0	104.0	11.2	76.0	<1,000
Barium	151	–	49	394	<1,000	60	<200	69.0	611	45.0	185	444	<1,000
Beryllium	1.6	–	<0.5	<1.1	–	<1.6	–	13.0	8.0	<0.11	2.4	0.4	–
Bismuth	52.0	–	42	26.0	–	<13	–	<5.77	<7.89	20.0	15.0	5.6	–
Cadmium	176	39.0	1008.0	26.0	<0.01	651	10,700	175	<0.53	6,276	367	0.37	8,600
Calcium	–	–	–	–	23,000	–	9.0	–	–	–	–	–	4,500
Chromium (T)	70,907	5,080	8,667	61,526	13,900	7,613	36,400	6,408	19,479	29,704	33,220	42,487	35,900
Chloride*	2,820	–	56,900	16,400	–	83,600	–	6,500	5,100	14,400	7,670	4,600	–
Copper	36,358	–	2,400	14,043	1,500	8,805	1,160	17,446	6,955	88,989	770	83,000	<1,000
Cyanide (T)	–	–	15	0.0	–	3.1	45.0	61.3	–	20.3	1,358	1,211	–
Iron	54,661	68,900	102,789	34,123	86,400	128,377	69,500	100,673	27,316	51,261	35,260	19,722	32,000
Fluoride*	0	–	200	200	–	57,500	–	1,800	3,000	2,000	–	–	–
Lead	3,739	57.0	411.0	2,298	<1,000	321	210	10,050	1,403	2,344	440	382	<1,000
Manganese	–	–	–	–	–	–	1,000	–	–	–	–	–	1,000
Magnesium	–	–	–	–	–	–	11,000	–	–	–	–	–	78,700
Mercury	0.15	–	16.0	<0.004	–	<0.006	–	<0.38	<1.8	<5.0	1.08	0.37	–
Nickel	71,816	1,260	2,500	48,065	<1,000	159,748	5,800	34,712	75,552	58,932	9,696	118,556	<1,000
Selenium	<30	–	0.2	6.6	<1,000	<0.006	<200	<9.61	<13.0	<5.68	<0.4	9.3	<1,000
Silver	2.0	–	332.0	0.0	–	0.0	<0.02	250.0	–	<0.3	716.0	130.0	–
Sodium	–	–	–	–	7,100	–	3,000	–	–	–	–	–	12,100
Tin	203	–	750	3,500	<1,000	2,000	1,260	39,827	<13.0	8,751	38.0	8,370	1,000
Zinc	9,642	140,000	215,055	2,585	362,500	792	256,400	47,269	11,440	95,511	172,640	15,900	356,600

All values in mg/l accept for percent solids.
*Dry weight basis.
PSXXX-Survey Respondents.

Exhibit 2-8. Summary of Potential Stakeholders

Stakeholder	Affected Groups	Impacts
Metal Platers	• Senior management	• Select, evaluate, and implement waste reduction options considering economic impact, product quality, and efficiency.
	• Mid-level management/environment staff	• Assess consumer willingness to accept changes and to pay more for environmental protection. • Assess changes in shop floor operations. • Assess availability of waste management to handle new waste streams.
	• Technicians and laborers	• Implement changes. • Train all employee levels.
Upstream	• Suppliers of raw materials, feedstocks, equipment, and other commodities • Generators of raw materials (ore extraction, beneficiation, and refining)	• Respond to reduced demand for raw materials and increased demand for alternative materials.
Downstream	• End-users	• Change technical design or specification for product.
	• Waste management	• Prepare for reduced, eliminated, or altered demand for services.
Policymakers and Regulators	• Environmental	• Assess impact of policy changes on all relevant stakeholders.
	• Domestic/international trade and commerce	• Assess consumer willingness to accept changes and to pay more for environmental protection.
Consumers	• All consumers	• Change attitude toward alternative materials and green products.

3.0 Waste Minimization/Pollution Prevention Techniques

3.1 General

This section presents an overview of the range of pollution prevention/waste minimization options available to metal finishers. The discussion is structured similarly to the U.S. Environmental Protection Agency's (USEPA) Environmental Management Options Hierarchy, shown in **Exhibit 3-1**. The highest priorities are given to preventing pollution through source reduction and recycling, including closed-loop recycling. This strategy minimizes or eliminates the need for off-site recycling or treatment and disposal. **Exhibit 3-2** indicates the optimal direction of a pollution prevention plan.

Metal finishers have numerous opportunities for source reduction, including environmental friendly design of new products, product changes, and process changes. Captive shops have a greater opportunity for product changes than do job shops because they control the design of the products. Both captive and job shops have reduced waste generation through process changes. Process changes have the greatest impact in minimizing the use of chlorinated solvents, cadmium, cyanide, and chromium. Numerous general waste reduction methods can be used by plating shops to reduce the formation of wastes. Often, these methods are non-capital intensive methods of waste reduction that can also reduce operating costs and improve the working environment of the shop. Most shops utilize conventional process solution maintenance methods that reduce the disposal rate of cleaning, plating, and other chemical baths. Advanced process solution maintenance technologies, such as microfiltration and membrane electrolysis, are also being applied that can indefinitely extend the life span of process solutions. Recovery of chemicals from rinse waters using technologies such as evaporation, ion exchange, and reverse osmosis can often be used in a closed-loop manner. Plating shops also use off-site recycling, where concentrated metal solutions and sludges are processed into useful raw materials.

3.2 Alternative Processes

The deposition of metal coatings, such as chromium, nickel, copper, and cadmium, is usually achieved by wet chemical processes that have inherent pollution control problems. Alternative metal deposition methods have replaced some of the wet processes and may play a greater role in metal coating in the future. This section discusses several of the more common alternative metal deposition processes.

Many of these processes have very high unit plating costs and, therefore, are currently used only for special applications where the cost of coating is not a major consideration. Also, the entire coating process must be considered when evaluating technology changes. In many cases, pre-cleaning and post-plating processes are unaffected and, therefore, some conventional tank processing is still required.

Alternative technologies for the metal finishing industry have several features in common that distinguish them from conventional treatment technologies. These features are described briefly below as a way of providing a background for understanding the specific technologies discussed in the remainder of this section:

- <u>Energy</u>—Surface treatment involves inputting energy into the surface of the work piece in order for adhesion to take place. Conventional surface finishing methods involve heating an entire part. The methods described in this section usually add energy and material into the surface, keeping the bulk of the object relatively cool and unchanged. This allows surface properties to be modified with minimal effect on the structure and properties of the underlying material. [11][1]
- <u>Plasmas</u>—The surface treatments described in this section (except for thermal spray) use plasmas (i.e., clouds of electrons and ions from which particles can be extracted). Plasmas are used to reduce process temperatures by adding energy to the surface in the form of kinetic energy of ions rather than thermal energy. [11]
- <u>Vacuum</u>—Advanced surface treatments (except most thermal spray and laser methods) require the use of vacuum chambers to ensure proper cleanliness and control. Vacuum processes are generally more expensive and difficult to use than liquid or air processes. Facilities can expect to see less complicated vacuum systems appearing on the market in the future. [11]

In general, use of the advanced surface treatments is more appropriate for treating small components (e.g., ion beam implantation, thermal spray) because the treatment time for these processes is proportional to the surface areas being covered. Facilities will also have to address the following issues when considering the new techniques [11]:

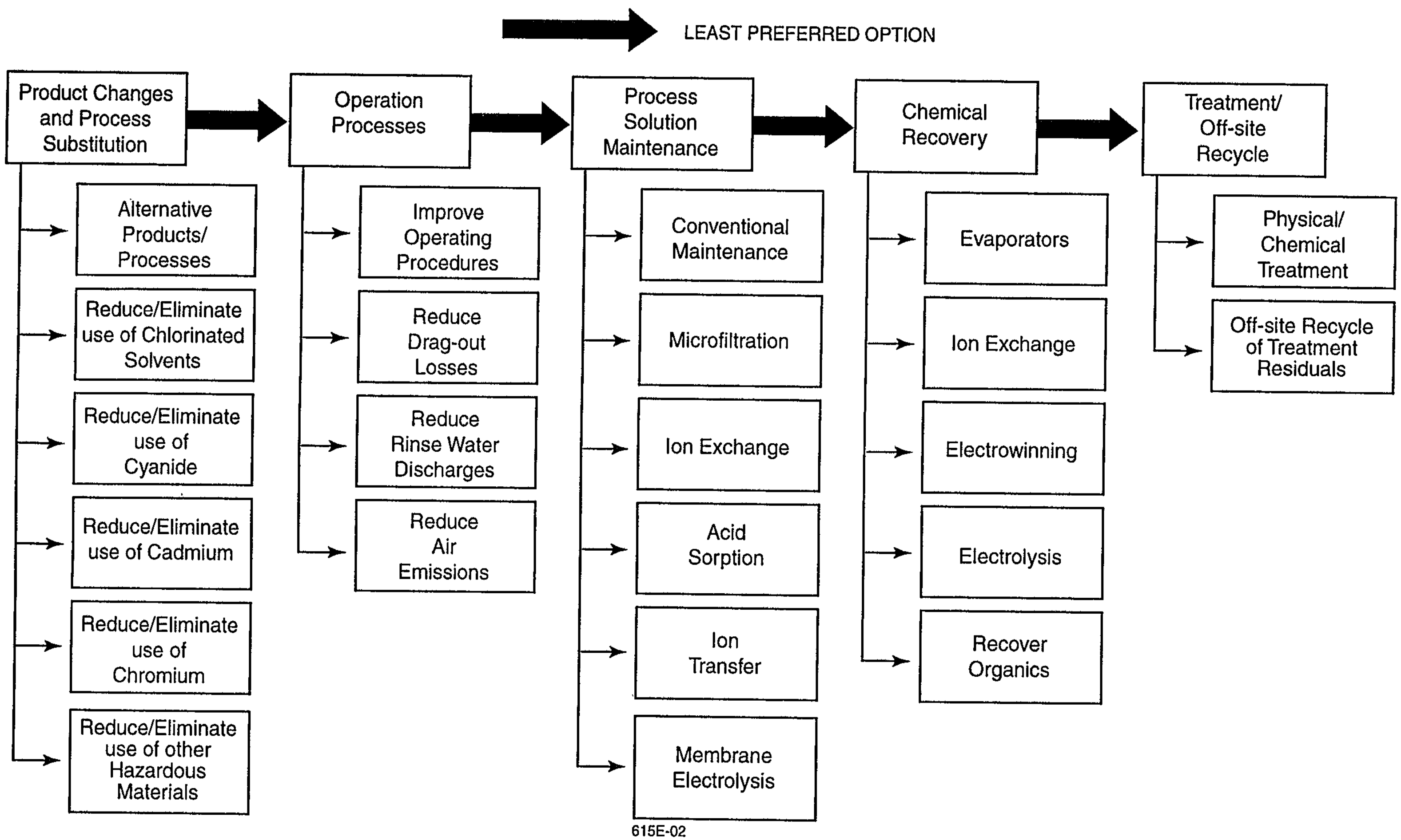
- Quality control methods: Appropriate quality assurance tests need to be developed for evaluating the performance of the newer treatment techniques.

Exhibit 3-1. EPA's Environmental Management Hierarchy

METHOD	EXAMPLE ACTIVITIES	EXAMPLE APPLICATIONS
Source Reduction (Highest Priority)	• Environmentally Friendly Design of New Products • Product Changes • Source Elimination	• Modify Product to Avoid Solvent Use • Modify Product to Extend Coating Life
Recycling	• Reuse • Reclamation	• Solvent Recovery • Metal Recovery from a Spent Plating Bath • Volatile Organic Recovery
Treatment	• Stabilization • Neutralization • Precipitation • Evaporation • Incineration • Scrubbing	• Thermal Destruction of Organic Solvent • Precipitation of Heavy Metal from a Spent Plating Bath
Disposal	• Disposal at a Permitted Facility	• Land Disposal

615E-14

Exhibit 3-2. Waste Minimization/Pollution Prevention Methods and Technologies



- Performance testing: New tribological tests must be developed for measuring the performance of surface engineered materials.
- Substitute cleaning and coating removal: The advanced coatings provide excellent adhesion between the substrate and the coating; as a result, these coatings are much more difficult to strip than conventional coatings. Many coating companies have had to develop proprietary stripping techniques, most of which have adverse environmental or health risks.
- Process control and sensing: The use of advanced processes requires improvements in the level of control over day-to-day production operations, such as enhanced computer-based control systems.

3.2.1 Organization of this Section

This section introduces some of the better known, advanced coating processes. The discussion includes a general overview of the technology's basic elements and process steps, specific techniques that fall within the broad technology class and their limitations and applicability, and the technology's current uses, relative cost, and waste generation/environmental and safety considerations. **Exhibit 3-3** outlines the advanced coating techniques presented in this section.

3.2.2 Thermal Spray Coatings

Technology Description

Coatings can be sprayed from rod or wire stock or from powdered materials. The material (e.g., wire) is fed into a flame where it is melted. The molten stock is then stripped from the end of the wire and atomized by a high velocity stream of compressed air or other gas, which propels the material onto a prepared substrate or workpiece. Depending on the substrate, bonding occurs either due to mechanical interlock with a roughened surface, due to localized diffusion and alloying, and/or by means of Van der Waals forces (i.e., mutual attraction and cohesion between two surfaces.

Process Description

The basic steps involved in any thermal coating process are substrate preparation, masking and fixturing, coating, finishing, inspection, and stripping (when necessary). Substrate preparation usually involves scale and oil/grease removal, as well as surface roughening. Roughening is necessary for most of the thermal spray processes to ensure adequate bonding of the coating to the substrate. The most common method is grit blasting usually with alumina. Masking and fixturing limit the amount of coating applied to the work piece in order to remove the overspray through time-consuming grinding and stripping after deposition. [11]

The basic parameters in thermal spray deposition are the particle's temperature, velocity, angle of impact, and extent of reaction with gases during the deposition process. The geometry of the part being coated affects the surface coating since the specific properties vary from point to point on each piece. Facilities should standardize these properties in their thermal spray process lines to minimize variations in the surface coating. [11]

Exhibit 3-3. Summary of Advanced Coating Technologies

Technology	Applications	Limitations
Thermal Spray Coatings • Combustion torch • Electric arc • Plasma sprays	Primarily repair operations although they are now being incorporated into original manufacturing	Technologies in varying states of development; commercial availability may be limited in certain cases
Vapor Deposition • Ion plating • Ion implantation • Sputtering and sputter deposition • Laser surface alloying	Primarily high-technology applications that can bear additional costs Expected to improve product quality and life	Expense often limits application to expensive parts (e.g., aerospace, electronics, military) May require improved process controls, employee training, and automation
Chemical Vapor Deposition	Used primarily for corrosion resistance and wear resistance in electronics	Start-up costs are typically very expensive.

In many applications, workpieces must be finished after the deposition process, the most common technique being grinding followed by lapping. The final inspection of thermal spray coatings involves verification of dimensions, an visual examination for pits, cracks, etc. Nondestructive testing has largely proven unsuccessful.

Unlike some of the other advanced coatings, thermal coatings can be stripped chemically in acids or bases, electrolytically, or in fused sales. If none of these techniques are possible, mechanical removal by grinding or grit blasting is necessary [11].

Specific Technologies

There are three basic categories of thermal spray technologies: combustion torch (flame spray, high velocity oxy-fuel, and detonation gun), electric (wire) arc, and plasma arc. Section 4.1 presents a brief description of each thermal spray technology, its limitations and applicability, and examples of specific applications.

Cost

Because the cost of using these systems depends on many factors, including their application, it is difficult to compare their costs. In general, it appears that flame spraying and high velocity oxy-fuel are relatively inexpensive in comparison to detonation gun, electric-arc, and plasma spray. [9][11]

Stage of Development

Thermal spray processes are maturing, and the technology is readily available. Coating manufacturers are introducing new coating compositions with improved microstructures. Improvement can still be made in the area of epoxy sealants and nondestructive testing.

Waste Generation/Environmental and Safety Considerations

Environmental concerns include the generation of dust, fumes, overspray, noise, and intense light. The metal spray process is usually performed in front of a "water curtain" or dry filter exhaust hood, which captures the overspray and fumes. Water curtain systems periodically discharge contaminated wastewaters. Noise generated can vary from approximately 80 dB to more than 140 dB. With the higher noise level processes, robotics are usually required for spray application.

The use of metal spray processes may eliminate some of the pollution associated with conventional tank plating. In most cases, however, wet processes, such as cleaning, are necessary in addition to the metal coating process. Therefore, complete elimination of tanks may not be possible.

Waste streams resulting from flame spray techniques may include overspray, wastewaters, spent exhaust filters, rejected parts, spent gas cylinders, air emissions (dust, fumes), and wastes associated with the grinding and finishing phases. For example, if chromium carbide is used with HVOF, disposal of the excess material may be a problem.

3.2.3 Vapor Deposition

Technology Description

Vapor deposition refers to any process in which materials in a vapor state are condensed through condensation, chemical reaction, or conversion to form a solid material. These processes are used to form coatings to alter the mechanical, electrical, thermal, optical, corrosion resistance, and wear properties of the substrates. They are also used to form free-standing bodies, films, and fibers and to infiltrate fabric to form composite materials. [11]

This section describes two categories of vapor deposition processes: physical (PVD) and chemical (CVD). In PVD processes, the workpiece is subjected to plasma bombardment. In CVD processes, thermal energy heats the gases in the coating chamber and drives the deposition reaction. Vapor deposition processes usually take place within a vacuum chamber.

Physical Vapor Deposition

Physical vapor deposition methods are clean, dry vacuum deposition methods in which the coating is deposited over the entire object simultaneously, rather than in localized areas. All reactive PVD hard coating processes combine:

- A method for depositing the metal
- Combination with an active gas, such as nitrogen, oxygen, or methane
- Plasma bombardment of the substrate to ensure a dense, hard coating. [3]

PVD methods differ in the means for producing the metal vapor and the details of plasma creation. The primary PVD methods are ion plating, ion implantation, sputtering, and laser surface alloying. Section 4.2 summarizes the four major PVD technologies in use.

Waste Management/Environmental and Safety Considerations

Wastestreams resulting from laser cladding are identical to those resulting from high velocity oxy-fuels and other physical deposition techniques: blasting media and solvents, bounce and overspray particles, and grinding particles. Generally speaking, none of these waste streams are toxic. [3]

Chemical Vapor Deposition

CVD is a subset of the general surface treatment process, vapor deposition. Over time, the distinction between the terms "physical vapor deposition" and "chemical vapor deposition" has blurred as new technologies have been developed and the two terms overlap. CVD includes sputtering, ion plating, plasma enhanced chemical vapor deposition, low pressure chemical vapor deposition, laser enhanced chemical vapor deposition, active reactive evaporation, ion beam, laser evaporation, and many other variations. These variants are distinguished by the manner in which precursor gases are converted into the reactive gas mixtures. [11]

In CVD processes, a reactant gas mixture impinges on the substrate upon which the deposit is to be made. Gas precursors are heated to form a reactive gas mixture. The coating species is delivered by a precursor material, otherwise known as a reactive vapor. It is usually in the form of a metal halide, metal carbonyl, a hydride, or an organometallic compound. The precursor may be in either gas, liquid, or solid form. Gases are delivered to the chamber under normal temperatures and pressures, while solids and liquids require high temperatures and/or low pressures in conjunction with a carrier gas. Once in the chamber, energy is applied to the substrate to facilitate the reaction of the precursor material upon impact. The ligand species is liberated from the metal species to be deposited upon the substrate to form the coating. Since most CVD reactions are endothermic, the reaction may be controlled by regulating the amount of energy input. [9]

The steps in the generic CVD process are:

- Formation of the reactive gas mixture
- Mass transport of the reactant gases through a boundary layer to the substrate
- Adsorption of the reactants on the substrate
- Reaction of the adsorbents to form the deposit
- Description of the gaseous decomposition products of the deposition process.

Section 4.2 provides information on sputtering, ion plating, and ion beam CVD. Section 4.3 describes the overall CVD process and includes limits and applicability and specific applications.

Waste Generation/Environmental and Safety Considerations

The precursor chemicals should be selected with care because potentially hazardous or toxic vapors may result. The exhaust system should be designed to handle any reacted and unreacted vapors that remain after the coating process is complete.

Other waste effluents from the process must be managed appropriately. Retrieval, recycle, and disposal methods are dictated by the nature of the chemical. For example, auxiliary chemical reactions must be performed to render toxic or corrosive materials harmless, condensates must be collected, and flammable materials must be either combusted, absorbed, or dissolved. The extent of these efforts is determined by the efficiency of the process. [9]

3.3 Product and Input Material Changes

This section covers product changes and input material changes, which are two key aspects of pollution prevention for metal finishing operations.

3.3.1 Product Changes

Product changes can be implemented to reduce the use of hazardous materials during finishing. Such changes often involve changing the composition of the base material. For example, changing from mild steel construction to stainless steel construction may eliminate all finishing steps for a given product.

The manufacturer is primarily responsible for product changes because they have control over the design and specification of the product. A recent study indicates that some job shops have input on the design of the parts that they plate and that they provide customer education for part modification and design. Some job shop plating companies indicated that they would not bid on work that generates excessive pollution.

3.3.2 Input Material Changes

Input material changes, such as using a less hazardous coating, can be implemented by either the manufacturer or metal finisher. Some input material changes are restricted by specifications or aesthetic preferences. Most input material changes made within this industry have focused on chlorinated solvents, cyanide, cadmium, and chromium.

Exhibit 3-4 summarizes key input material changes in the metal finishing industry. The following discussion highlights the industry's efforts in reducing the use of chlorinated solvents, cyanide, cadmium, and chromium.

Chlorinated Solvents

The most commonly used chlorinated degreasing solvents include 1,1,1 trichloroethane (TCA), trichloroethylene (TCE), perchloro-ethylene (PERC), chlorofluorocarbons (or solvent 113), and methylene chloride. A variety of methods are employed for

Exhibit 3-4. Status of Material Substitution

Hazardous Material	Conventional Process	Percent Conversion	Alternative Processes
Chlorinated Solvents	Vapor/Immersion Degreasing	25 - 50	– Aqueous Cleaning – Semi-Aqueous Cleaning – Alternative Solvents – Salt Bath Cleaning
Cyanide	Zinc Cyanide Plating	> 75	– Zinc Chloride – Zinc Alkaline – Zinc Sulfate
	Copper Cyanide Plating	25 - 75	– Alkaline Non-Cyanide – Acid Copper Baths
	Cadmium, Silver, and Gold Plating	< 25	– Non-Cyanide Baths
Cadmium	Cadmium Plating	25 - 75*	– Zinc Plating – Zinc Nickel – Other Alloys – Ion Vapor Deposition of Aluminum
Chromium	Decorative Chromium	25 - 50	– Trivalent Chromium Plating – Painting
	Hard Chromium	<25	– Electroless Nickel – Nickel Alloys – Metal Sprays
	Chromic Acid Anodizing	<25	– Sulfuric Acid Anodizing – Sulfuric/Boric Acid Anodizing
	Conversion Coating/ Desmut/Deox	<50	– Trivalent Chromate – Non-Chromium Solutions

* Success depends greatly on the application.

degreasing, the most popular being vapor degreasers, immersion or spray operations, and hand wiping.

Data from a recent study show that approximately one-quarter of the plating shops that used chlorinated solvents in 1980 (approximately one-half of the U.S. shops used chlorinated solvent in 1980) have eliminated use of this material. The study also shows that newer plating shops (i.e., those established since 1980) are even less likely to use chlorinated solvents. Moreover, the study indicates that the average quantity of solvent used by shops has declined by approximately 25 percent since 1980. This reduction in the usage rate is due to the implementation of equipment and operational changes that reduce evaporative losses of solvent and to the use of recovery devices.

Alternative cleaning methods substituted for chlorinated solvents include:

- Tanks containing non-chlorinated materials, which are replacing vapor degreasers. The tanks are used like other metal finishing process tanks.
- Automatic parts washers.

Input material changes, including the ones given in the following list, mostly focus on aqueous and semi-aqueous cleaning substances:

- New cleaners that permit light oils to float and heavy soils to sink, extending the life of the cleaner.
- Equipment such as skimmers and filters that separate the soils from the cleaning bath.

- Semi-aqueous cleaners, including water-immiscible types (e.g., terpenes, esters, petroleum hydrocarbons, and glycol ethers) and water-miscible types (e.g., alcohols, ketones, and amines). Semi-aqueous cleaners have better solvency properties than do aqueous cleaners. However, there are some drawbacks with their use, including oily films left on parts, air emissions, and disposal problems. As a result, the general preference is to use aqueous cleaning rather than semi-aqueous cleaning. Some soils are not adequately removed by aqueous products (e.g., buffing compounds), however, and semi-aqueous chemistry is needed.

Numerous other input material and equipment substitutions are being used or investigated by the metal finishing industry, including (1) non-ozone depleting solvents that are used as drop-in replacements in conventional chlorinated solvent equipment (includes hydrochlorofluorocarbons [HCFCs], (2) perfluorocarbons (PFCs), which are used in new vapor degreasing tanks for cleaning heavily soiled parts or parts requiring a high quality cleaning process, (3) supercritical fluids (e.g., CO_2), which are an emerging technology with limited application, and (4) molten salt baths, which are used widely but have limited application.

Cost differences between conventional chlorinated solvent cleaning and the alternative methods vary widely depending on the specific application. In addition, chlorinated solvent cleaning costs are changing rapidly because of decreases in material production and increases in disposal costs. Prior to recent changes in environmental laws governing chlorinated solvents, the cost of using these materials was relatively low.

Cyanide

Cyanide-containing plating baths produce high-quality coatings. However, these baths pose a problem in terms of both pollution control compliance and economics. In the United States, cyanide effluent limitations are often set locally at concentrations far below the federal standards.[2] As a result, there has been a significant effort to find and implement cyanide-free plating processes since approximately 1975.

The greatest success so far in cyanide substitution is the switch from zinc cyanide plating to zinc chloride and zinc alkaline plating. One significant drawback with regard to zinc cyanide plating substitution is that some shops find it necessary to install both zinc chloride and zinc alkaline baths to replace the single cyanide bath. On a positive note, in addition reducing the use of cyanide, some platers enjoy production benefits from the substitution, including better and brighter plating.

The second most complete non-cyanide plating substitution is the switch from copper cyanide plating to alkaline non-cyanide and acid copper baths. Similar to zinc plating, shops switching to non-cyanide copper must often implement two processes.

Cadmium, silver, and gold are almost exclusively plated from cyanide baths, although non-cyanide substitutes are available for all three metals. In each case, the substitutes have limited application or are significantly inferior in terms of deposit quality.

With the elimination of cyanide, so is the need to chlorinate the cyanide for the treatment of cyanide. This eliminates the cyanide complexes formed in the plating bath and improves treatment efficiency. This also eliminates the need for segregated cyanide plumbing, reducing maintenance costs and hazard exposure.

In summary, much of the plating workload that was once processed in cyanide baths is now being processed in non-cyanide baths. Overall, cyanide usage by U.S. metal finishing shops has decreased by 50 percent or more since 1980. Many plating shops have completely eliminated the use of cyanide. Because most non-cyanide substitutes do not cover the range of applications of their cyanide counterparts, however, the majority of these shops have had to reduce their customer base to eliminate cyanide use.

Cadmium

Many alternatives to cadmium plating exist, with no single universal substitute available. Some cadmium plating alternatives are zinc plating, tin or tin alloy plating, cobalt-zinc plating, zinc-nickel plating, zinc-iron plating, zinc-flake dispersion coating, metallic ceramic coating, and ion vapor deposition of aluminum. The most successful of these alternatives has been zinc-nickel plating, which has a long history in the electroplating industry. Generally, for alternatives to be successful, they must provide sufficient corrosion resistance, as measured by standard tests (e.g., salt fog test). For certain military and aerospace applications, the alternative deposits must also provide other desired characteristics, such as lubricity.

Many electroplating job shops have eliminated cadmium plating because of a reduced market and the enforcement of local discharge standards that are often much more restrictive than the federal limitations. In addition, many captive shops and military shops have reduced or eliminated the use of cadmium plating (e.g., Tinker Air Force Base, Oklahoma).

Chromium

Chromium is used most often with decorative chromium plating. This process is traditionally performed with a hexavalent chromium bath, but trivalent chromium plating has increased in use, especially during the past 10 years. With either process, an undercoat of nickel/copper or nickel is usually applied. Instead of using chromium plating, some platers have replaced steel parts with noncorrosive materials, such as stainless steel, and used organic coatings (paint). An example of chromium plating displacement is automobile bumpers. Although some chromium plating has been replaced, it is still one of the most frequently applied electroplates.

Trivalent chromium plating is an economically attractive alternative to hexavalent plating for some applications. However, its use has been limited due to a difference in appearance from the standard hexavalent bath. The trivalent bath chemistry is more expensive to purchase than the hexavalent bath. The cost savings are a result of reduced metal loadings on the treatment system (the trivalent bath contains less total chromium) and the avoidance of the hexavalent chromium reduction step during treatment. One source estimates that, considering treatment costs, the cost of trivalent chromium plating is about one-third of the costs for hexavalent solution (ref. 2).

Hard chromium plating is applied to tools, hydraulic cylinders, and other metal surfaces that require wear resistance. The major difference between the hard chromium and decorative deposits is their thickness. The hard chromium deposit is typically hundreds of times thicker than decorative ones. Although research efforts have aimed at a trivalent chromium substitute for hard chromium plating, no solutions are available commercially. Input material changes for hard chromium have focused on alternative deposits. Alternative processes have also been used. The most successful alternative input material is electroless nickel (ref. 14). Other alternative input materials under investigation are electroplated nickel alloys (e.g., amplate) and nickel alloy composites (e.g., Boeing Ni-W-SiC). Alternative processes to hard chromium plating include brush plating, vacuum coating, and metal sprays (see Section 3.2 for discussions of vacuum deposition and metal sprays).

During the past several years, the U.S. Air Force has investigated alternative input materials and processes for hard chromium. The results of these efforts indicate that substitutions can be made on a case-by-case basis.

Chromium use with aluminum finishing is perhaps most common in the aerospace industry. Chromium combines with aluminum on the surface of parts to provide corrosion and wear resistance and a chemically active surface for painting or coloring. The two most common processes are chromic acid anodizing and chromate conversion coating. These are not competing processes, but rather each has a specific role. Both processes are performed in hexavalent chromium baths. The anodizing process is electrolytically performed and the conversion coating process involves simple immersion. Significant research efforts have been undertaken during the past 10 years to find alternatives to these processes. For many applications, alternatives have been identified and implemented. For example, chromic acid anodizing has been partially replaced by common sulfuric acid anodizing and sulfuric/boric acid anodizing, and chromium baths have been replaced to a lesser extent by non-chromium conversion coatings (e.g., permanganate, rare earth metals and zirconium oxide) (ref. 15).

Another use of chromium during aluminum finishing is for deoxidizing/desmutting. These preliminary processes (sometimes a combined single step) remove oxides and other inorganics that would interfere with aluminum processing (e.g., anodizing). Alternatives to the chromium-based products include iron and ammonium salts or amines mixed with various oxidizers and/or etchants. Owing to the extent of research for non-chromium aluminum finishing and the success rate of these efforts, it is feasible that chromium use will eventually be eliminated from the aluminum finishing area. One would expect to see large-scale substitutions during the next 10 years. However, total elimination will take considerable longer because of small residual uses of chromium for which no satisfactory substitute exists and because of the complexity of the military and aerospace specifications that presently require the use of chromium.

3.4 General Waste Reduction Practices

3.4.1 Improved Operating Procedures

Employee Education

A high level of employee awareness and education is an essential part of any company's overall environmental program. The success or failure of specific procedures depends largely on employee attitudes toward that policy. The employees must discern a company-wide effort supported at all levels of management that affords the tools and data to ensure success.

Employee training should cover minimization or prevention of waste generation at the source, routine process chemistry additions and sample-taking, handling of spills and leaks, and operation of pollution prevention and control technologies. Background information should be made available to employees, such as an outline of the applicable regulations, overall benefits to health and safety in and out of the workplace, and overall costs of waste treatment before and after the successful implementation of waste minimization procedures. This training should be integrated with normal operator training, and pollution prevention and control procedures should be included in the written operating procedures for each process.

Chemical Tracking, Inventory, and Purchasing Control

Records of chemical purchases, inventory, bath analyses, dumps and additions, water usage, wastewater treatment chemical usage, and spent process bath and sludge analyses must be kept in order to gather an overview of a shop's material balance and waste treatment costs. From these records, data can be gathered and used to determine the success of an overall minimization policy. Process-specific material balance block diagrams can be drawn and shared with operators. These diagrams illustrate origins of waste production clearly and can also be used to re-engineer plating lines to reduce chemical loss.

Standardization of materials used throughout a shop can greatly reduce chemical inventory, thereby reducing costs. Decisions to purchase one chemical rather than another must consider technical requirements, environmental impacts, and cost.

3.4.2 Drag-Out Reduction

Drag-out of process fluid into rinse water is a major source of pollution in any plating shop. The volume of drag-out discharged from a process is determined by some factors that cannot be altered easily, such as part shapes and process fluid concentrations. The effects of many other contributing factors, however, are readily reduced by common techniques. Reduction of drag-out not only reduces the mass of pollutants reaching the wastewater stream but also reduces the amount of chemical loss suffered by the process. Because most of the drag-out reduction methods discussed in this section require only operator training or small process changes, the cost savings and other benefits realized quickly offset any implementation expenses incurred. Section 4.4 summarizes drag-out reduction techniques.

3.4.3 Rinse Water Use Reduction

Reducing water usage offers several benefits, including reduced water costs, higher waste treatment efficiency, size reduction of future waste treatment and pollution control technologies, and reduction in the use of treatment chemicals. Water usage cannot be reduced indiscriminately without risking process problems. Rinse tanks must maintain a target concentration of contamination, above which part quality may suffer. Several inexpensive methods can significantly reduce water consumption, however, without affecting rinse contaminant concentrations. Section 4.5 summarizes techniques for reducing rinse water.

3.4.4 Air Emissions Reduction

The release of chlorinated solvents can be reduced through design changes to degreasing equipment and good operating practices. Examples of design changes include increased freeboard, automatic rolltop, hoist speed control, and refrigeration zone. Examples of good operating practices include covering unused degreasing and the "stop-and-go" part removal technique. Chromium air emissions can be reduced through process changes and the use of capture/recycle control devices.

3.5 Process Solution Maintenance

3.5.1 Conventional Maintenance Methods

The most common conventional bath maintenance method is filtration. Nearly all plating baths require filtration to remove suspended solids that would otherwise adhere to the surface of parts and cause rough plating. Small tanks can be filtered effectively by in-tank designs also keeping tanks covered when not in use; larger tanks usually require external pump and filter assemblies. Disposable cartridge filters made of wound or woven plastic are the most common filter type, followed by sand and diatomaceous earth.

Electrolysis or "dummy plating" is a method of reducing the mass of contaminant metals in a plating bath by plating them onto a dummy panel. Dummy plating can be performed directly in the plating tank or, to prevent down time, it can be done inside the tank. During dummy plating, a current density much lower than that used for normal plating is applied. The precise current density is determined by the process bath and the contaminants.

Chemical treatment inducing the precipitation of certain contaminants is effective for some plating baths. Carbonates in potassium cyanide baths can be precipitated with the addition of calcium hydroxide. Sodium sulfide can be added to cyanide plating baths to precipitate such metals as zinc or lead. Precipitation is usually performed in a spare tank and the precipitate is remove by filtration.

Carbonate freezing is applicable to sodium-based cyanide plating baths. When cooled to a temperature of approximately 3°C, sodium carbonate crystals form and can be removed easily.

Carbon treatment is a common method of reducing organic contamination in plating baths. Carbon treatment may only consist of occasionally substituting carbon for normal cartridges in the existing filtration equipment.

Alternately, filter columns containing several kilograms of bulk-activated carbon can be used for heavy organic loading. Nickel and copper plating solutions usually require regular carbon treatment.

3.5.2 Advanced Maintenance Technologies

This section discusses advanced maintenance technologies: microfiltration, ion exchange, acid sorption, ion transfer. Section 4.6 presents these technologies in greater detail.

Microfiltration

Microfiltration is a relatively new, membrane-based technology applied primarily to aqueous and semi-aqueous cleaning solutions. Oil and grease that accumulate in these baths degrade their cleaning efficiency although most bath constituents remain usable. This technology separates emulsified oils and other colloids from the cleaner chemistry, thereby extending the life of the process bath. **Exhibit 3-5** presents a typical microfiltration application.

Ion Exchange

Ion exchange as a bath maintenance technology is limited, for the most part, to cation removal from chromic acid solutions. Cations, such as copper, zinc, or iron, are introduced into chromic acid plating baths from parts and racks. They are tolerated to a point, beyond which plating performance is affected and the bath must be purified or discarded. For chromic acid purification, ion exchange competes with ion transfer and membrane electrolysis. **Exhibit 3-6** illustrates two types of ion exchange configurations.

Acid Sorption

Acid sorption is an acid purification technology applicable to various acid solutions, such as pickling or sulfuric acid anodizing baths. Acid is purified by the removal of dissolved metal. (Diffusion dialysis is another method for purifying acid.) Acid sorption is not commonly used by the plating industry. **Exhibit 3-7** presents a typical acid sorption configuration.

Ion Transfer

Ion transfer is a common technology with applications generally restricted to chromic acid plating baths, etches, and anodizing baths. Equipment can be in-tank or external. Designs range from low-cost, in-tank, small porous pots to large multi-cell automated units with integrated rectifiers and transfer pumps. As with the other chromic acid purification technologies, the goal of this technology is to selectively remove cations from chromic acid process fluids. Cr^{+3} oxidation to Cr^{+6} occurs at the anode. **Exhibit 3-8** shows a typical ion transfer configuration.

3.6 Chemical Recovery Technologies

Chemical recovery technologies either recover dragout and return it to the process (vacuum evaporation, electrodialysis, and reverse osmosis) or recover a constituent of the dragout chemistry, usually a dissolved metal, and re-use or recycle it in another process (electrowinning, metal scavenging, ion exchange). Recovering drag-out reduces raw material costs by returning otherwise lost components to the process and reduces the mass of regulated ions reaching the waste treatment system, which lowers costs and aids in complying with discharge limits.

Recovery technologies discussed in this section require at least some, and in many cases extensive, engineering and planning. With the possible exception of some electrowinning and evaporation applications, the feed stream requires complete characterization. Ion exchange and reverse osmosis equipment capacities and other design characteristics must be customized to these data. The level of customization and engineering required for certain installations can represent a significant portion of capital costs and can make small feed stream volumes expensive to treat. Capital and operating costs mentioned in this section are typical; specific costs can vary widely. Installation and set-up costs are site- and application-specific and can match or exceed equipment costs in some cases. Labor costs are difficult to predict but are usually much higher than expected with manual, undersized, or poorly planned and engineered installations. Section 4.7 describes chemical recovery technologies, including their typical applications, restrictions, and costs.

3.6.1 Evaporation

Evaporation with atmospheric and vacuum systems is the most common chemical recovery technology used in the plating industry. Atmospheric evaporators are most common, are relatively inexpensive to purchase, and easy to operate. Vacuum evaporators are mechanically more sophisticated and are more energy efficient; therefore, they are usually the choice for applications where evaporation rates greater than 50 to 70 gallons per hour (190-265 liters per hour) are required. Additionally, with vacuum evaporators, water lost as vapor can be recovered as a condensate and re-used in the plant. **Exhibit 3-9** shows two typical evaporation designs.

Exhibit 3-5. Example of Microfiltration Application

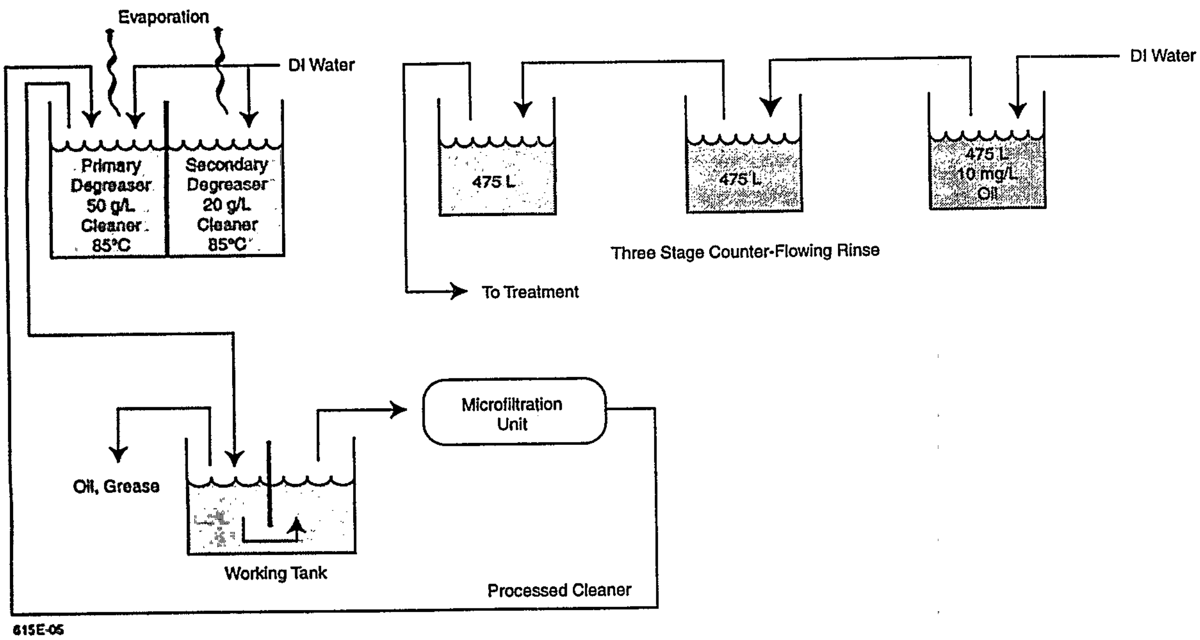


Exhibit 3-6. Two Common Configurations of Ion Exchange for Bath Maintenance

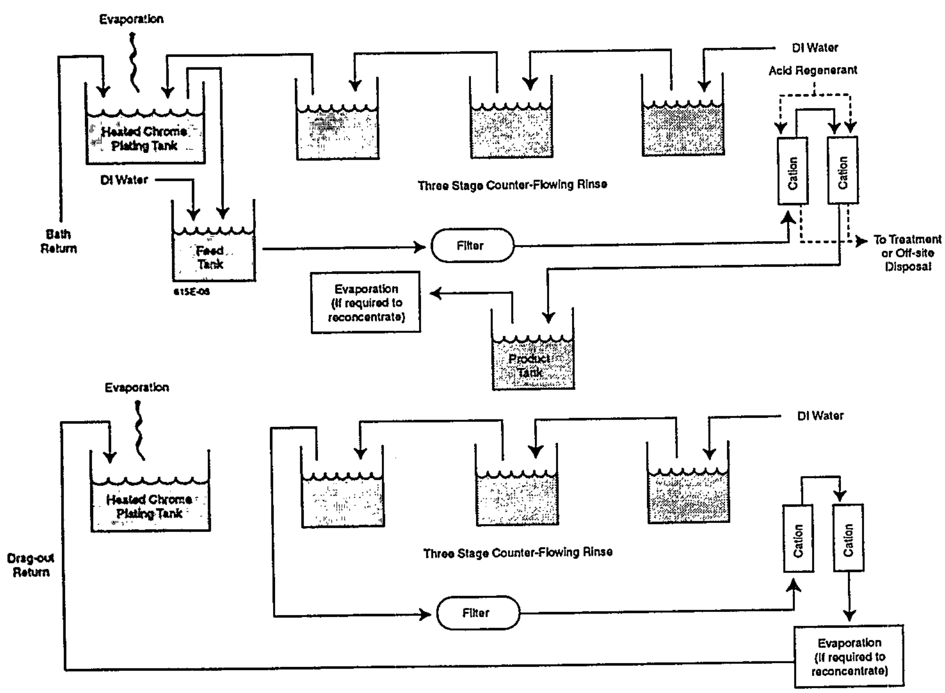


Exhibit 3-7. Typical Acid Sorption Configuration

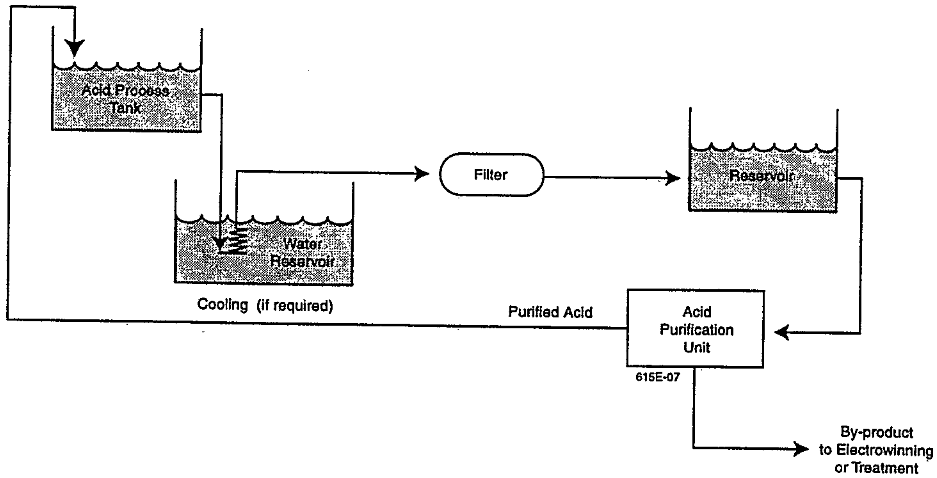


Exhibit 3-8. Typical Ion Transfer Configuration

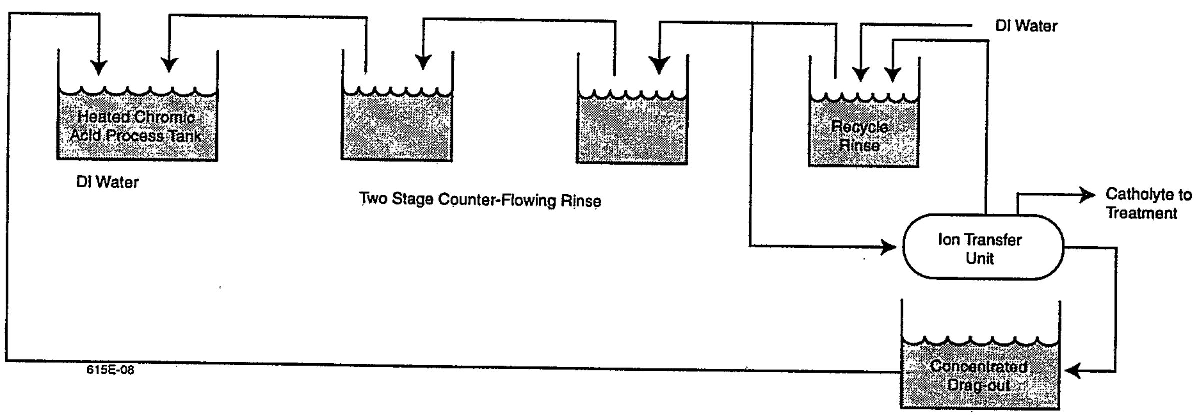
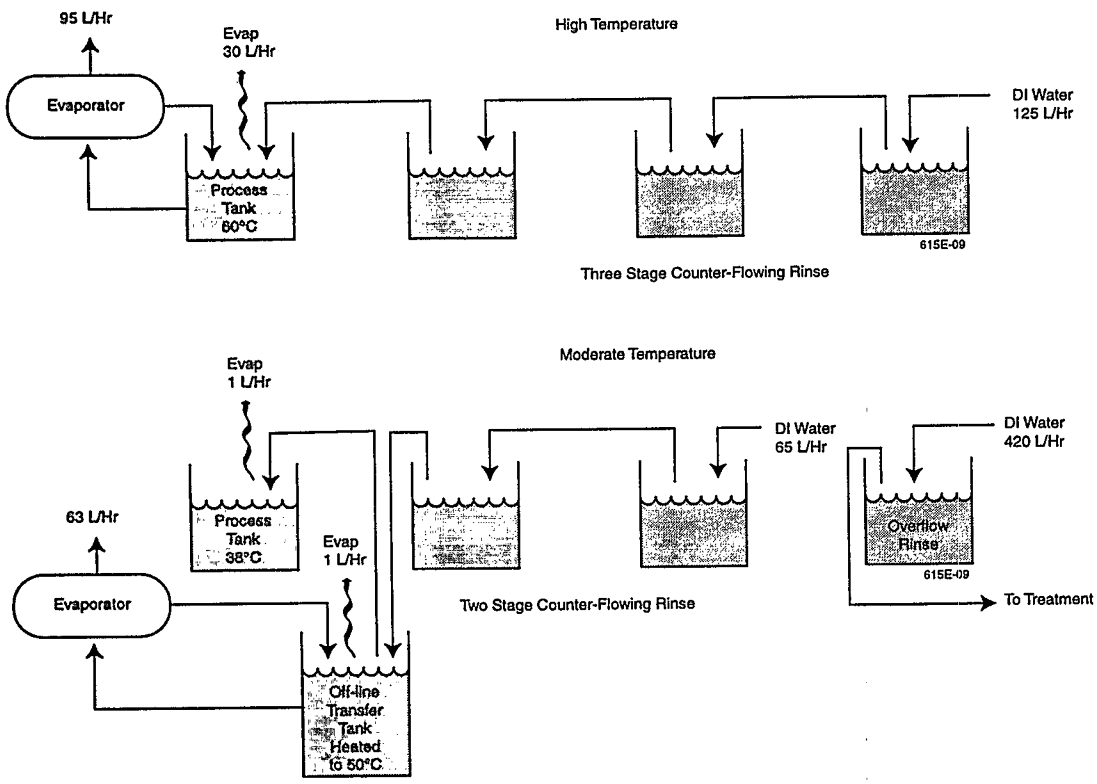


Exhibit 3-9. Two Common Configurations for the Application of Atmospheric Evaporators



3.6.2 Ion Exchange

Ion exchange is a versatile technology that can be a major component of a low- or zero-discharge configuration or it can be employed to selectively remove certain cations from a rinse stream. In either case, ion exchange can only be applied to relatively dilute streams and is best employed in association with other conventional drag-out recovery practices. In many applications, ion exchange is used to recycle rinse water. In a few cases, the ion exchange regenerant, which contains the recovered process chemistry, can be returned to the process tank directly. In most cases, however, the regenerant is electrowinned or treated conventionally. **Exhibit 3-10** presents common ion exchange system configurations.

3.6.3 Electrowinning

Electrowinning is a well-known and common recovery technology. It is limited, however, because only the metal portion of the process chemistry is recovered, making direct return of the metal-depleted drag-out usually impossible. The technology is generally inexpensive both to purchase and operate.

Electrowinning is applied to drag-out fluids, spent process baths, or ion exchange regenerant, all of which are relatively concentrated with metal ions. It is used to reduce the mass of regulated metals being discharged to a main treatment center, in turn reducing the quantity of treatment reagents needed and sludge produced. When applied to precious metals, the value of the metal recovered may be the primary consideration. For the less expensive recovered metals, the value of the recovered metal is usually a secondary or incidental benefit. **Exhibit 3-11** illustrates two common electrowinning contributions.

3.6.4 Electrodialysis

Electrodialysis is employed with much less frequency for metal recovery than some other technologies, such as ion exchange or evaporation. The most common application of electrodialysis is the recovery of nickel from rinse water. A considerable portion of the drag-out from a nickel process can be separated from the rinse water and returned to the nickel bath. One advantage unique to this technology is that organic molecules are prevented from entering the concentrate flow and therefore are not returned to the

Exhibit 3-10. Common Ion Exchange Configurations for Chemical Recovery

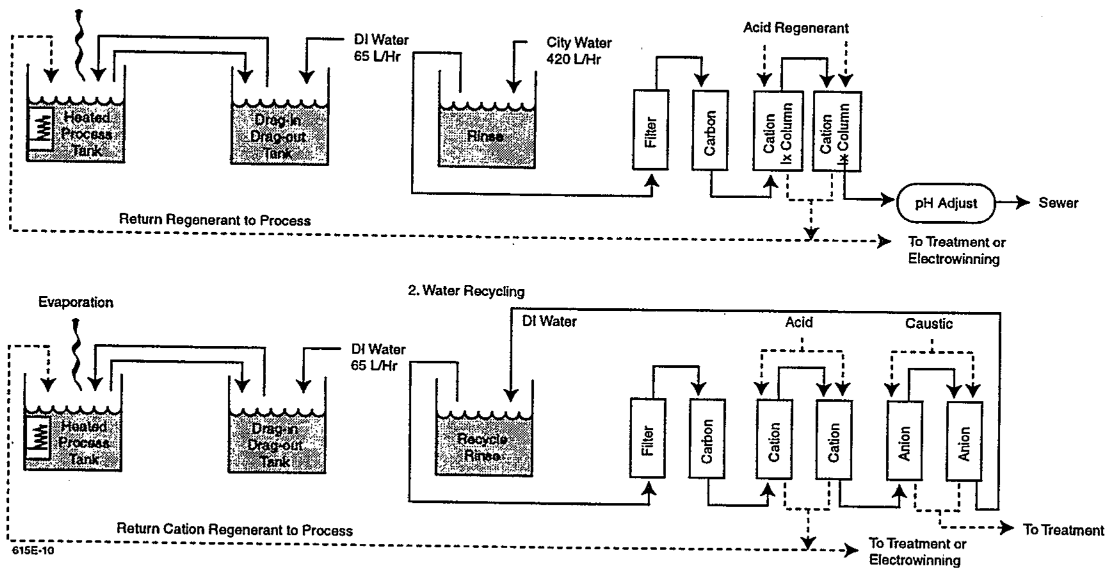
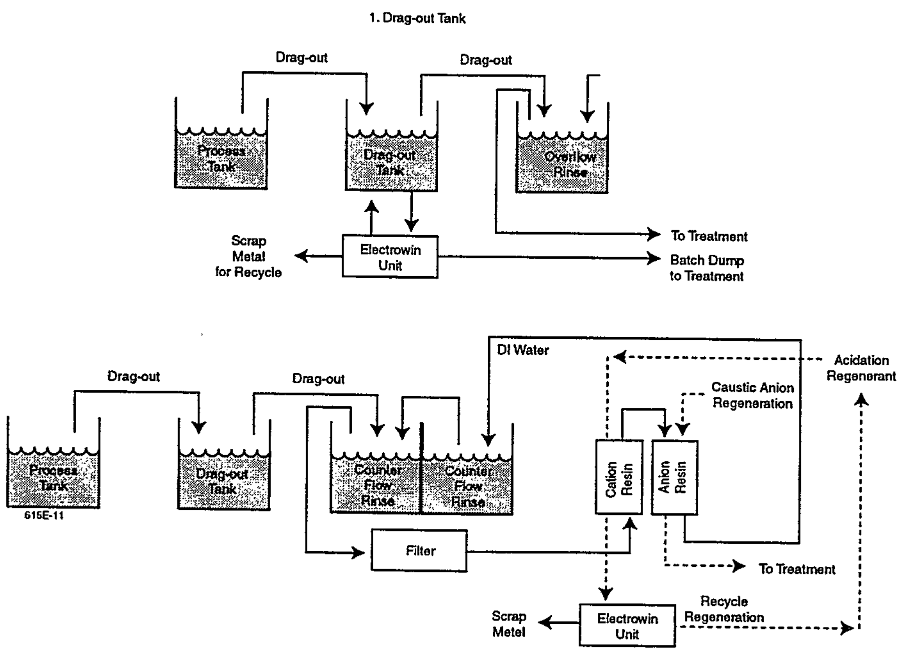


Exhibit 3-11. Two Common Electrowinning Configurations for Metal Recovery



process tank, making electrodialysis particularly suitable for recovery of process fluids in which an undesirable build-up of organics occurs. **Exhibit 3-12** presents a schematic of a nickel plating line with electrodialysis.

3.6.5 Reverse Osmosis

Reverse osmosis is a membrane filtration technology that has been applied to a single rinse stream from a process or to a mixed stream from several processes. The portion of the flow that passes through the membrane is usually recycled as rinse water or the portion of the flow rejected by the membrane and containing most of the dissolved solids is often suitable for direct return to the process tank. Reverse osmosis is a good component of a low- or zero-discharge configuration. Reverse osmosis equipment is usually more expensive than ion exchange, and the quality of the recycled water is somewhat lower. **Exhibit 3-13** presents a typical reverse osomsis configuration for nickel recovery.

3.7 Off-Site Metals Recycling

Approximately one-third of U.S. plating shops send their metal bearing wastewater treatment sludges to off-site metals recycling companies rather than to land disposal. The recycling companies separate the metals from the sludge and convert them to usable materials. Some off-site facilities also accept and process spent chemical solutions.

3.7.1 Available Services

Off-site metals recycling services in the United States were previously limited to spent solvents, precious metal wastes, and high purity common metal wastes. Since 1985, there has been a steady increase in the use of off-site recycling, primarily because of the availability of recycling services for wastewater treatment sludges, rising costs for land disposal, and increased generator concern over the liability associated with land disposal.

Companies that recycle metals accept limited types of wastes, depending on their permit issued by USEPA. Of the companies identified as metals recyclers, for example, only seven can accept wastewater treatment sludge. One company specializes in processing cyanide bearing wastes, and another accepts mostly spent solutions from printed circuit board manufacturing.

Exhibit 3-12. Flow Schematic of Nickel Plating Line Before and After Installation of Electrodialysis

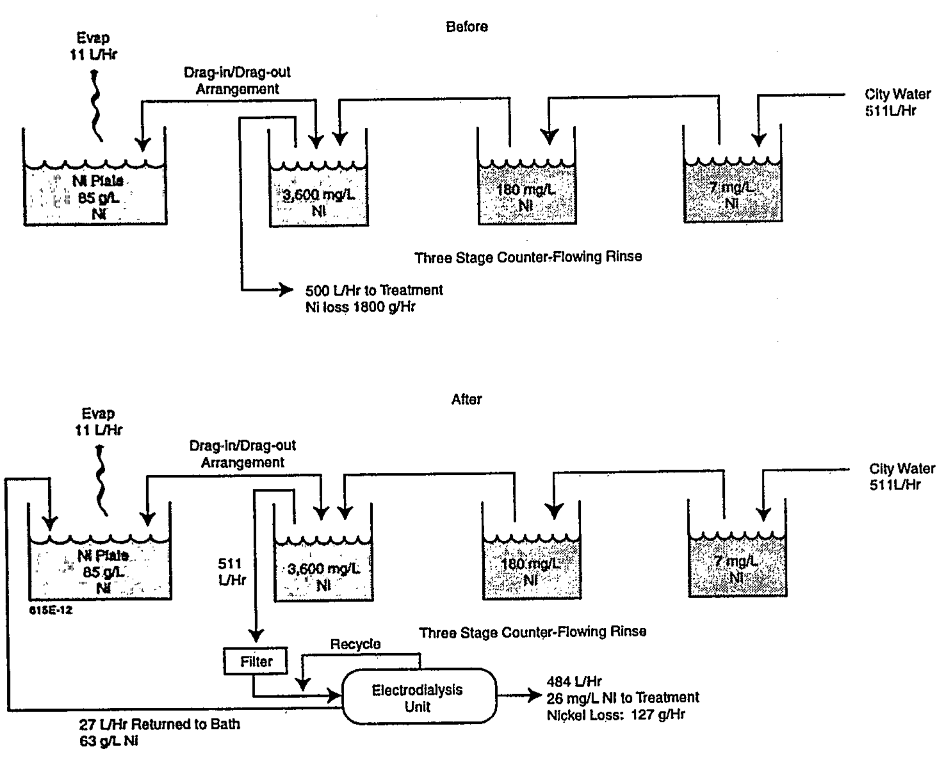
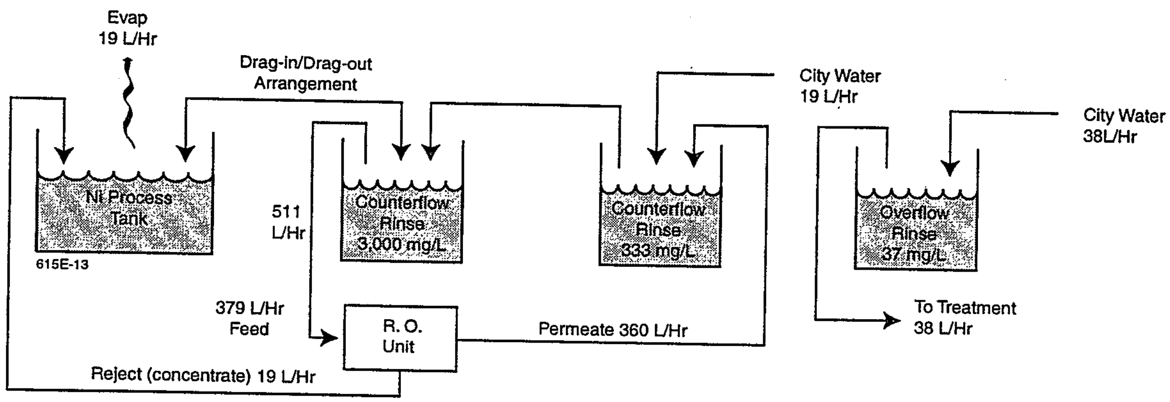


Exhibit 3-13. Typical Reverse Osmosis Configuration for Nickel Recovery



The present U.S. capacity for recycling wastewater treatment sludges has been estimated to be 1.1 million tons per year. At present, approximately one-third of this capacity is being used. Various recovery processes are employed by the off-site recycling companies to convert wastewater treatment sludge into usable products. Most of these processes can be categorized as pyrometallurgical or hydrometallurgical processes. A typical facility processes 25,000 to 150,000 tons of waste material per year.

3.7.2 Recycling Costs

Various factors affect the price charged by off-site recyclers. These factors include competition, sludge type (hydroxide sludges are preferred to sulfide sludges), metal constituents of the waste (mono-metal sludges are preferred to mixed metal sludges), moisture content (preferred content varies from facility to facility depending on equipment type), waste volume (higher volumes mean lower prices), chemical consistency from shipping to shipment, and hauling distance (average U.S. distance is approximately 700 miles). Prices charged by off-site recycling companies vary widely with the median price being $0.30 per pound, including transportation. By comparison, the cost for land disposal of sludges is $0.25 per pound, including transportation. Many plating companies appear willing to pay a slightly higher price for recycling perhaps because of the liability associated with land disposal, since waste generators can be financially responsible for the clean-up costs of Superfund sites. One source estimated a liability factor of $0.02/lb.

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Endnotes

[1] See reference #11; for this section on thermal spraying, the particular chapter of reference #11 is called "Thermal Spray Coatings" and was written by Robert C. Tucker, Jr., of Praxair Surface Technology, Inc. pp. 161-177.

[2] There is an emotional factor involved with cyanide because it is widely been regarded as a deadly poison. Because of its notoriety, cyanide is probably feared more by the general public than many compounds that pose significantly greater environmental and health risks.

4.0 EXAMPLES OF WASTE MINIMIZATION/ POLLUTION PREVENTION TECHNIQUES

4.1 Thermal Spray Technologies

4.1.1 Combustion Torch/Flame Spraying

Flame spraying involves the use of a combustion flame spray torch in which a fuel gas and oxygen are fed through the torch and burned with the coating material in a powder or wire form and fed into the flame. The coating is heated to near or above its melting point and accelerated to speeds of 30 to 90 m/s. The molten droplets impinge on the surface where they flow together to form the coating.

Limits and Applicability

Flame spraying is noted for its relatively high as-deposited porosity, significant oxidation of the metallic components, low resistance to impact or point loading, and limited thickness (typically 0.5 to 3.5 mm). Advantages include the low capital cost of the equipment, its simplicity, and the relative ease of training the operators. In addition, the technique uses materials efficiently and has low associated maintenance costs.

Specific Applications

This technique can be used to deposit ferrous-, nickel-, as well as cobalt-based alloys, and some ceramics. It is used in the repair of machine bearing surfaces, piston and shaft bearing or seal areas, and corrosion and wear resistance for boilers and structures (e.g., bridges).

4.1.2 Combustion Torch/High Velocity Oxy-Fuel (HVOF)

With HVOF, the coating is heated to near or above its melting point and accelerated in a high-velocity combustion gas stream. Continuous combustion of oxygen fuels typically occurs in a combustion chamber, which enables higher gas velocities (550 to 800 m/s). Typical fuels include propane, propylene, MAPP, or hydrogen.

Limits and Applicability

This technique has very high velocity impact, and coatings exhibit little or no porosity. Deposition rates are relatively high, and the coatings have acceptable bond strength. Coating thicknesses range from 0.000013 to 3 mm. Some oxidation of metallics or reduction of some oxides may occur, altering the coating's properties.

Specific Applications

This technique may be an effective substitute for hard chromium plating for certain jet engine components. Typical applications include reclamation of worn parts and machine element build-up, abradable seals, and ceramic hard facings.

4.1.3 Combustion Torch/Detonation Gun

Using a detonation gun, a mixture of oxygen and acetylene with a pulse of powder is introduced into a water-cooled barrel about 1 meter long and 25 mm in diameter. A spark initiates detonation, resulting in hot, expanding gas that heats and accelerates the powder materials (containing carbides, metal binders, oxides) so that they are converted into a plastic-like state at temperatures ranging from 1,100 to 19,000°C. A complete coating is built up through repeated, controlled detonations.

Limits and Applicability

This technical produces some the densest of the thermal coatings. Almost any metallic, ceramic, or cement materials that melt without decomposing can be used to produce a coating. Typical coating thicknesses range from 0.05 to 0.5 mm, but both thinner and thicker coatings are used. Because of the high velocities, the properties of the coatings are much less sensitive to the angle of deposition than most other thermal spray coatings.

Specific Applications

This can only be used for a narrow range of materials, both for the choice of coating materials and as substrates. Oxides and carbides are commonly deposited. The high-velocity impact of materials such as tungsten carbide and chromium carbide restricts application to metal surfaces.

4.1.4 Electric Arc Spraying

During electric arc spraying, an electric arc between the ends of two wires continuously melts the ends while a jet of gas (air, nitrogen, etc.) blows the molten droplets toward the substrate at speeds of 30 to 150 m/s.

Limits and Applicability

Coating thicknesses can range from a few hundredths of a mm to almost unlimited thickness, depending on the end use. Electric arc spraying can be used for simple metallic coatings, such as copper and zinc, and for some ferrous alloys. The coatings have high porosity and low bond strength.

Specific Applications

Industrial applications include coating paper, plastics, and other heat sensitive materials for the production of electromagnetic shielding devices and mold making.

4.1.5 Plasma Spraying

A flow of gas (usually based on argon) is introduced between a water-cooled copper anode and a tungsten cathode. A direct current arc passes through the body of the gun and the cathode. As the gas passes through the arc, it is ionized and forms plasma. The plasma (at temperatures exceeding 30,000°C) heats the powder coating to a molten state and compressed gas propels the material to the workpiece at very high speeds that may exceed 550 m/s.

Limits and Applicability

Plasma spraying can be used to achieve thicknesses from 0.3 to 6 mm, depending on the coating and the substrate materials. Sprayed materials include aluminum, zinc, copper alloys, tin, molybdenum, some steels, and numerous ceramic materials. With proper process controls, this technique can produce coatings with a wide range of selected physical properties, such as coatings with porosities ranging from essentially zero to high porosity.

Specific Applications

This techniques can be used to deposit molybdenum and chromium on piston rings, cobalt alloys on jet-engine combustion chambers, tungsten carbide on blades of electric knives, and wear coatings for computer parts.

4.2 Physical Vapor Deposition Technologies

4.2.1 Ion Plating/Plasma Based

Plasma-based plating is the most common form of ion plating. The substrate is in proximity to a plasma and ions are accelerated from the plasma by a negative bias on the substrate. The accelerated ions and high-energy neutrals from charge exchange processes in the plasma arrive at the surface with a spectrum of energies. In addition, the surface is exposed to chemically "activated" species from the plasma and adsorption of gaseous species form the plasma environment.

Limits and Applicability/Current Development

This technique produces coatings that typically range from 0.008 to 0.025 mm. Advantages include a wide variety of processes as sources of the depositing material; in-situ cleaning of the substrate prior to film deposition; excellent surface covering ability; good adhesion; flexibility in tailoring film properties such as morphology, density, and residual film stress; and equipment requirements and costs equivalent to sputter deposition. Disadvantages include many processing parameters must be controlled; contamination may be released and "activated in the plasma; and bombarding gas species may be incorporated in the substrate and coating

Current Uses/Specific Applications

Coating materials include alloys of titanium, aluminum, copper, gold, and palladium. Plasma-based ion plating is used in the production of x-ray tubes; space applications; threads for piping used in chemical environments; aircraft engine turbine blades; tool steel drill bits; gear teeth; high tolerance injection molds; aluminum vacuum sealing flanges; decorative coatings; corrosion protection in nuclear reactors; metallizing of semi-conductors, ferrites, glass, and ceramics; and body implants. In addition, it is widely used for applying corrosion resistant aluminum coatings as an alternative to cadmium.

Costs

Capital costs are high for this technology, creating the biggest barrier for ion plating use. It is used where high value-added equipment is being coated such as expensive injection molds instead of inexpensive drill bits.

4.2.2 Ion Plating/Ion Beam Enhanced Deposition (IBED)

During IBED, both the deposition and bombardment occur in a vacuum. The bombarding species are either ions from an ion gun or other sources. While ions are bombarding the substrate, neutral species of the coating material are delivered to the substrate via a physical vapor deposition technique such as evaporation or sputtering. Since the secondary ion beam is independently controllable, the energy particles in the beam can be varied over a wide range and chosen with a very narrow window. This allows the energies of deposition to be varied to enhance coating properties such as interfacial adhesion, density, morphology, and internal stresses. The ions form nucleation sites for the neutral species resulting in islands of coating which grow together to form the coating.

Limits and Applicability/Current Development

Advantages include increased adhesion; increased coating density; decreased coating porosity and prevalence of pinholes; and increased control of internal stress, morphology, density, and composition. Disadvantages include high equipment and processing costs; limited coating thicknesses; part geometry and size are limited; and gas precursors used for some implantation species are toxic. This technique can produce a chromium deposit 10 microns thick with greater thicknesses attained by layering. Such thicknesses are too thin for most hard chrome requirements (25 to 75 microns with some dimensional restoration work requiring 750 microns) and layering would significantly add to the cost of the process. IBED provides some surface cleaning when surface is initially illuminated with a flux of high energy inert gas ions; however, the process will still require precleaning (e.g., degreasing).

Current Uses/Specific Applications

Although still an emerging technology, IBED is used for depositing dense optically transparent coatings for specialized optical applications, such as infrared optics.

Costs

Capital costs are high for this technology, creating the biggest barrier for ion plating use. Equipment for IBED processing could be improved by the development of low-cost, high-current, large-area reactive ion beam sources.

4.2.3 Ion Implantation

Ion implantation does not produce a discrete coating; the process alters the elemental chemical composition of the surface of the substrate by forming an alloy with energetic ions (10-200 keV in energy). A beam of charged ions of the desired element (gas) is formed by feeding the gas into the ion source where electrons, emitted from a hot filament, ionize the gas and form a plasma. The ions are focused into a beam using an electrically biased extraction electrode. If the energy is high enough, the ions will go into the surface, not onto the surface, changing the surface composition. Three variations have been developed that differ in methods of plasma formation and ion acceleration: beamline implantation, direct ion implantation, and plasma source implantation. Pretreatment (degreasing, rinse, ultrasonic cleaner) is required to remove any surface contaminants prior to implantation. Process is performed at room temperature, and time depends on the temperature resistance of the workpiece, and the required dose.

Limits and Applicability/Current Development

Ion implantation can be used for any element that can be vaporized and ionized in a vacuum chamber. Since material is added to the surface, rather than onto the surface, there is no significant dimensional change or problems with adhesion. The process is easily controlled, offers high reliability and reproducibility, requires no post-treatment, and generates minimal waste. If exposed to high temperatures, however, implanted ions may diffuse away from the surface due to limited depth of penetration and penetration does not always withstand severe abrasive wear. Implantation is used to alter surface properties, such as hardness, friction, wear resistance, conductance, optical properties, corrosion resistance, and catalysis. Commercial availability is limited by general unfamiliarity with the technology, scarcity of equipment, lack of quality control and assurance, and competition with other surface modification techniques. Areas of research includes ion implantation of ceramic materials for high temperature internal combustion engines, glass to reduce infrared radiation transmission and reduce corrosion, as well as automotive parts (piston rings, cylinder liners) to reduce wear.

Current Uses/Specific Applications

Nitrogen is commonly implanted to increase the wear resistance of metals since ion beams are produced easily. In addition, metallic elements, such as titanium, yttrium, chromium, and nickel, may be implanted into a variety of materials to produce a wider range of surface modifications. Implantation is primarily used as an antiwear treatment for components of high value such as biomedical devices (prostheses), tools (molds, dies, punches, cutting tools, inserts), and gears and ball bearings used in the aerospace industry. Other industrial applications include the semiconductor industry for depositing gold, ceramics, and other materials into plastic, ceramic, and silicon and gallium arsenide substrates. The U.S. Navy has demonstrated that chromium ion implantation could increase the life of ball bearings for jet engines with a benefit to cost ratio of 20:1. However, the Navy has not equipped its jets with ion-implanted bearings. The U.S. Army is investigating the possibility of ion-implanted helicopter components and other applications as a substitute for chromium electrodeposits. A treated forming die resulted in the production of nearly 5,000 automobile parts compared to the normal 2,000 part life from a similar tool hard faced with tank plated chromium.

Costs

The initial capital cost is relatively high, although large-scale systems have proven cost effective. An analysis of six systems manufactured by three companies found that coating costs range form $0.04 to $0.28 per square centimeter. Depending on throughput, capital costs ranges from $400,000 to $1,400,000, and operating costs were estimated to range from $125,000 to $250,000.

4.2.4 Sputtering and Sputter Deposition

Sputtering is an etching process for altering the physical properties of the surface. The substrate is eroded by the bombardment of energetic particles, exposing the underlying layers of the material. The incident particles dislodge atoms from the surface or near-surface region of the solid by momentum transfer form the fast, incident particle to the surface atoms. The substrate is contained in a vacuum and placed directly in the path of the neutral atoms. The neutral species collides with gas atoms, causing the material to strike the substrate from different directions with a variety of energies. As atoms adhere to the substrate, a film is formed. The deposits are thin, ranging from 0.00005 to 0.01 mm. The most commonly applied materials are chromium, titanium, aluminum, copper, molybdenum, tungsten, gold, silver, and tantalum. Three techniques for generating the plasma needed for sputtering are available: diode plasmas, RF diodes, magnetron enhanced sputtering.

Limits and Applicability/Current Development

This technique is a versatile process for depositing coatings of metals, alloys, compounds, and dielectrics on surfaces. The process has been applied in industrial hard and protective coatings. Primarily TiN, as well as other nitrides and carbides, has demonstrated high hardness, low porosity, good chemical inertness, good conductivity, and attractive appearance.

Sputtering is capable of producing dense films, often with near bulk quantities. Areas requiring future research and development include better methods for in-situ process control; methods for removing deposited TiN and other hard, ceramic-like coatings from poorly coated or worn components without damage to the product; and improved understanding of the factors the affect film properties.

Current Uses/Specific Applications

Sputter-deposited films are routinely used simply as decorative coatings on watchbands, eyeglasses, and jewelry. The electronics industry relies heavily on sputtered coatings and films (e.g., thin film wiring on chips and recording heads, magnetic and magneto-optic recording media). Other current applications for the electronics industry are wear-resistant surfaces, corrosion resistant layers, diffusion barriers, and adhesion layers. Sputtered coatings are also used to produce reflective films on large pieces of architectural glass, and for the coating of decorative films on plastic in the automotive industry. The food packaging industry uses sputtering for coating thin plastic films for packaging pretzels, potato chips, and other products.

Costs

Compared to other deposition processes, sputter deposition is relatively inexpensive.

4.2.5 Laser Surface Alloying

The industrial use of lasers for surface modifications is increasingly widespread. Surface alloying is one of many kinds of alteration processes achieved through the use of lasers. It is similar to surface melting but it promotes alloying by injecting another material into the melt pool, so that the new material alloys into the melt layer.

Laser cladding is one of several surface alloying techniques performed by lasers. The overall goal is to selectively coat a defined area. In laser cladding, a thin layer of metal (or powder metal) is bonded with a base metal by a combination of heat and pressure. Specifically, ceramic or metal powder is fed into a carbon dioxide laser beam above a surface, melts in the beam, and transfers heat to the surface. The beam welds the material directly into the surface region, providing a strong metallurgical bond. Powder feeding is performed by using a carrier gas in a manner similar to that used for thermal spray systems. Large areas are covered by moving the substrate under the beam and overlapping disposition tracks. Shafts and other circular objects are coated by rotating the beam. Depending on the powder and substrate metallurgy, the microstructure of the surface layer can be controlled, using the interaction time and laser parameters.

Pretreatment is not as vital to successful performance of laser cladding processes as it is for other physical deposition methods. The surface may require roughening prior to deposition. Grinding and polishing are generally required post-treatments.

Limits and Applicability/Current Development

This technique can be used to apply most of the same materials that can be applied via thermal spray techniques; the powders used for both methods are generally the same. Materials that are easily oxidized, however, will prove difficult to deposit without recourse to inert gas streams and envelopes.

Deposition rates depend on laser power, powder feed rates, and traverse speed. The rates are typically in the region of $2\times10\text{-}4$ cm^3 for a 500 watt beam. Thicknesses of several hundred microns can be laid down on each pass of the laser beam allowing thicknesses of several millimeters to accumulate. If the powder density is too high, this thermal cycling causes cracking and delamination of earlier layers, severely limiting the attainable build-up.

The Advanced Research Products Agency at Northwestern University has found that easily oxidized materials, such as aluminum, cannot be laser clad because the brittle oxide causes cracking and delamination. Some steels may be difficult to coat effectively. The small size of the laser's beam limits the size of the workpieces that can be treated cost effectively. Shapes are restricted to those that prevent line-of-sight access to the region to be coated.

Current Uses/Specific Applications

Although laser processing technologies have been in existence for many years, industrial applications are relatively limited.

Uses of laser cladding include to change the surface composition to produce a required structure for better wear, high temperature performance; build up a worn part; provide better corrosion resistance; impact better mechanical properties; and enhance the appearance of metal parts.

Costs

The high capital investment required for using laser cladding has been a barrier for its widespread adoption by industry.

4.3 Chemical Vapor Deposition

4.3.1 Process Description

Substrate pretreatment is important in vapor deposition processes particularly in the case of CVD. Pretreatment of the surface involves minimizing contamination by mechanical and chemical means before mounting the substrate in the deposition reactor. Substrates must be cleaned just prior to deposition and the deposition reactor chamber itself must be clean, leak-tight, and free from dust and moisture. During coating, surface cleanliness is maintained to prevent particulates from accumulating in the deposit. Cleaning is usually performed using ultrasonic cleaning and/or vapor degreasing. Vapor honing may follow to improve adhesion. Mild acids or gases are used to remove oxide layers formed during heat-up.

Post treatment may include a heat treatment to facilitate diffusion of the coating material into the material.

Limits and Applicability

CVD is used mainly for purposes of corrosion resistance and wear resistance. CVD processes are also usually applied in cases where specific properties of materials of interest are difficult to obtain by other means. CVD is unique because it controls the microstructure and/or chemistry of the deposited material. The microstructure of CVD deposits depends on chemical makeup and energy of atoms, ions, or molecular fragments impinging on the substrate; chemical composition and surface properties of the substrate; substrate temperature; and presence or absence of a substrate bias voltage.

The most useful CVD coatings are nickel, tungsten, chromium, and titanium carbide. Titanium carbide is used for coating punching and embossing tools to impart wear resistance.

Current Uses/Specific Applications

CVD processes are used to deposit coatings and to form foils, powders, composite materials, free-standing bodies, spherical particles, filaments, and whiskers. CVD applications are expanding both in number and sophistication. The U.S. market in 1998 for CVD applications was $1.2 billion, 77.6 percent of which was for electronics and other large users, including structural applications, optical, optoelectronics, photovoltaic, and chemical. Analysts anticipate that future growth for CVD technologies will continue to be in the area of electronics. CVD will also continue to be an important method for solving difficult materials problems.

CVD processes are commercial realities for only a few materials and applications.

Costs

Start-up costs are typically very expensive.

4.4 Drag-Out Reduction Techniques

4.4.1 Plating Solution Control

Plating solutions can be controlled to minimize drag-out by:

- Reducing bath viscosity can decrease drag-out between baths. One of the most common methods is to operate the plating process at the lowest concentration possible. Another common method is to operate at the highest temperature possible.
- Adding wetting agents to reduce surface tension and minimized drag-out.
- Preventing the build-up of contaminants in process tanks improves performance. Contaminants such as carbonate must be removed in order to minimize drag-out. One method is to monitor carbonate accumulation in cyanide baths and keep levels as low as possible.
- Keeping solution covered to reduce contamination.
- Use high purity electrode to reduce impurities from falling out and contaminating the solution.

Impacts

Plating solution control has the following impacts:

- Lower viscosity reduces the volume of drag-out generated, and lowers the mass of constituents in the drag-out.

- Drag-out volume can be reduced up to 50 percent.
- Reduction of plating bath viscosities reduces drag-out.

4.4.2 Positioning Parts on Rack

Properly positioning the parts on the rack is important both for quality as well as drag-out reduction considerations. The best position is typically determined by experimentation. Common practices include: parts should not be racked over one another; they should be positioned to consolidate the runoff streams and oriented so that the lowest profile emerges from the fluid as the rack is removed.

Impacts

Properly positioning the parts on the rack reduces drag-out and maintains quality.

4.4.3 Withdrawal Rates and Drainage

One of the most critical factors is the speed with which the part is withdrawn from the bath. Three techniques are:

- Maximizing drip time
- Using drip shields or boards to capture and return drag-out as a rack or barrel is transported away from the process; using drip tanks to collect drag-out
- Utilizing air knives to enhance drainage

Impacts

Withdrawal rates and drainage can:

- Reduce drag-out volume, but loses time. However, lost time is made up because less time is needed for drainage over the tank
- Maximum drag-out volume is directly returned to tank
- Capture additional drag-out for return to plating tank
- Enhance drainage but may have ventilation problems as well as accelerated oxidation and passivation. Parts may dry completely in spots causing staining.

4.4.4 Rinsing Over Process Tanks

Fog or spray rinsing over the process tank where heated processes provide enough evaporative headroom to accept additional fluid. Automatic or manual sprayers are effective. Fog rinsing is used when limited evaporative headroom is available.

Impacts

This techniques reduces drag-out volume. It can cause complications with ventilation systems by possibly increasing the airborne pollutant load. Positioning of the spray nozzles is critical.

4.4.5 Drag-Out Tank

A drag-out tank is a rinse tank that is initially filled with water but is stagnant and drag-out accumulates in the tank. The contents of the tank are used to replenish drag-out and evaporative losses occurring in the process tank. Water is added to the drag-out tank to maintain the operating level.

Impacts

Effective when used after heated process tanks that can tolerate the return of diluted process chemistry. Little benefit if evaporative headroom is not created in the process tank.

4.4.6 Drag-In Drag-Out tank

Positioning a drag-in drag-out rinse before and after the plating tank ensures that drag-out is returned to the process at the same rate at which it is removed.

Impacts

More effective in low-temperature processes than drag-out rinsing alone. Requires an extra processing step, and build up of contaminants is accelerated.

4.5 Rinse Water Reduction Techniques

4.5.1 Tank Design

Tanks should be sized to allow for the rinsing of the largest parts, and all tanks (rinse and process) should be the same size. Inlet and outlet points should be at opposite sides of the tank and the flow into the tank should be distributed. Agitation may be achieved through air spaying or other methods.

Impacts

Optimum rinse tank design removes drag-out from the parts quickly, and rapidly disperses the drag-out in the rinse water. Allows for shorter dwell times and lower the concentration of contaminants that may remain on the part surface after rinsing. Spray rinsing may be preferred for flat parts.

4.5.2 Flow Controls

Flow through the rinse tanks should be closely monitored and/or controlled. Install flow restrictors to regulate flow. Install conductivity controller to regulate flow based on rinse water conductivity. When the conductivity reaches a set point, the valve is opened and water flows through the tank. When the conductivity falls below the set point, the valve is shut off. Timer release controls typically consist of a button, when pressed, opens the valve for a predetermined length of time. After the time has expired, the valve is automatically shut. The timer may require manual activation by the operator or may be activated by the action of racks and hoists.

Impacts

Some sort of flow control will reduce waste. Rinse tanks with manual valves are impossible to control. Flow restrictors maintain constant flow regardless of pressure and are available to control rates from <0.5 to 40 liters per minute. Flow controls are most effective when used in processes requiring continuous rinse flow. Intermittent rinsing operations are best controlled with timer rinse controllers. Conductive controllers are more sophisticated, but require additional parameters must be considered: daily/seasonal conductivity fluctuations; non-ionic contaminants and suspended solids are not sensed; and instruments require maintenance, calibration, and replacement probes. When timer controls are used in conjunction with flow restrictors, flow can be completely controlled.

4.5.3 *Rinsing Configuration*

A simple overflow rinse is very inefficient. Insert a drag-out rinse or counterflowing rinse series between the overflow rinse and the process. A counterflowing rinse series consists of a series of tanks were fresh water enters the tank furthest from the process tank and overflows into the next tank closer to the process tank, in the opposite direction of the work flow. As work runs through a counterflowing series, the first tank becomes more concentrated than the next. The flow rate is calibrated to achieve the desired concentration in the last, or cleanest tank.

Impacts

Rinsing configurations can reduce the amount of water required for rinsing. The flow in a two-stage counterflowing rinse can be calculated by multiplying the drag-out by the square root of the rinsing ratio. Thus, if 2,500 liters are required to dilute a liter of drag-out in an overflowing rinse, only 50 liters are required in a two-stage counterflowing rinse.

Cascade rinsing will eliminate the water usage in the rinse system that uses the recycled water. Additional benefits may be realized from the specific contamination present. For example, rinses after alkaline cleaners are more efficient if they are acidic, thus, acidic rinse water is cascaded to alkaline cleaner rinses.

Spray rinsing generally uses one-fourth the water of an overflow rinse, but is limited to flat parts. An effective configuration is a combination drag-out spray rinse where the parts are lowered below the fluid level in the tank, then sprayed over the tank as they exit

Determining the optimum combination depends on the evaporation rate of the process tank, the drag-out rate, the desired rinse water quality, various cost factors, and available floor space.

4.6 Summary of Advanced Maintenance Technologies

4.6.1 *Microfiltration*

The feed stream entering a microfiltration unit is typically filtered by conventional methods (e.g., cartridge filter) to remove large particulates. Various holding tank designs are then employed to trap or skim off floating oils and to allow heavier solids to settle. The fluid is then pumped into the membrane compartment of the unit where remaining oils and grease are rejected by the membrane while water, solvent and other cleaning bath constituents pass through. The fluid flows parallel to the membrane with enough velocity to sweep the reject off the surface.

Ceramic membranes are available in various pore sizes ranging from several hundred angstroms to over 0.2 microns. The appropriate pore size is determined by the specific cleaner to be filtered. The capacity of a unit is based on the total area and flux rate of the membrane. Flux rates range from 17 to more than 40 liters per m^2 per day, depending largely on pore size. Commercially available units range in capacity from less than 1,000 to more than 5,000 liters per day.

Applications and Restrictions

Not all cleaners are good candidates and a shop may be forced to change bath chemistry in order to employ microfiltration. High silicate cleaners are known to plug membranes. Dissolved metal ions, such as aluminum or copper, are not removed by microfiltration membranes. Cleaners that accumulate metal ions are generally not appropriate microfiltration applications because the bath life remains limited by rising metal concentration.

Costs

Capital costs range from $15,000 to $20,000 for a 1,000 liter per day unit to $25,000 to $30,000 for a 5,000 liter per day unit. Sizing is based on the bath volume and contaminant loading of the bath. A 1,000 liter per day unit will maintain a cleaning bath that processes approximately 1,000 m^2 of oil coated parts. Operating costs consist of electricity, membrane and other parts replacement, and labor. Membrane life is at least several and perhaps more than 10 years. Little data exists quantifying other costs, but they are generally expected to be low. For most applications, reduced chemistry usage and lower waste production lead to cost savings that more than offset operating costs and payback periods of 1 year to 2 years may be expected.

4.6.2 Ion Exchange

These units are constructed similarly to those described for recovery applications and consist of a resin column and a pump which circulates the process fluid. A selective cation resin is employed for chromic acid applications. The resin has an affinity for all cations, including Cr^{+3}. Cr^{+3} is dislodged from resin sites, however, by several other common tramp metal species. If enough fluid is pumped through the resin, most of the Cr^{+3} that was initially bound to the resin will be dislodged and returned to the process bath along with Cr^{+6} (which behaves as an anion and is not attracted by the resin), leaving the resin loaded with tramp metals. This specific selectivity of certain resins permit the application of ion exchange to tri-valent chromium plating baths as well.

A typical system would include 0.03 to 0.2 m^3 of resin contained in one or two columns. Multi-column configurations are not usually necessary because continuous service is not required. Flow rates of 3 to 10 liters per minute through the resin column are typical. Most units are semi-automatic and regeneration is initiated by the operator. The regeneration station may be elsewhere in the shop to preserve space near the plating tank, and the column is brought to the station by forklift or hand truck. Regeneration timing is usually calculated based on estimates of bath contamination and is considerably less important than for recovery applications of ion exchange because when fully loaded the ion exchange resin will have no effect on the process fluid and all constituents are simply returned to the bath. For hexavalent chromic acid plating baths, sulfuric acid is the most common regenerant. The regenerant volume is 150 liters or more per 0.1 m^3 of resin (combined sulfuric acid and rinse water).

Applications and Restrictions

The typical resin capacity is approximately 2,000 grams per 0.1 m^3. Units are sized to require relatively infrequent regenerations but also to maintain the process bath at low concentrations of tramp metals (usually less than 3 grams/liter of combined metals).

Ion exchange does not re-oxidize trivalent chrome. Conventional methods of oxidation, such as dummy plating, will be necessary if tri-valent chromium accumulation occurs. There is also some chrome loss with this technology. Even when run to exhaustion, a small proportion of chromium to tramp metals still remains and is discharged from the process during regeneration.

Costs

Capital costs depend on the capacity and automation level of the system. The resin used for chromic acid applications is quite expensive, approximately \$2,000/0.1 m^2. A unit with 0.1 m^3 of resin will cost approximately \$50,000 with a regeneration station. A major component of operating costs is resin replacement. Resin life depends on the application but is generally 1 year or less. Labor costs vary with installation but are not usually high when compared to other technologies in this section. Savings are generated from reduced chromic acid usage and waste.

4.6.3 Acid Sorption

A bed of strongly basic anion exchange resin separates the acid from the metal ions. The acid is taken up by the resin while the metal ions pass. The acid is then desorbed from the resin by water. The flow through the resin bed alternates between acid and water. First, spent acid is pumped upward through the bed. A metal-rich, mildly acidic solution passes and is collected at the top of the bed. Then, water is pumped downward through the bed and desorbs the acid from the resin and the purified acid solution is collected at the bottom of the bed. Approximately 80 percent of the free acid remaining in a spent acid solution can be recovered with this technology. Purification can be done in a batch mode, but the advantage of having a steady metal concentration is realized when employed in a continuous flow mode. Capacity is determined by the size of the resin bed and is usually expressed in terms of the mass of metal removed from the acid solution. Equipment capacities range from 100 grams/hour to several thousand grams/hour. Units are sized to remove metal near or above the rate at which metal is being introduced. Typically, a target level of metal concentration is determined and the unit is sized to maintain that level.

Applications and Restrictions

Many acid solutions common in plating shops are potential applications of acid sorption. Filtration is usually necessary while cooling is required for hot solutions and those containing oxidizers, which can generate heat as they enter the resin bed. The by-product, or the metal-rich solution which passes the resin bed, is sent to treatment. Some by-product solutions are suitable for electrowinning. In addition to anodizing and pickling baths, ion transfer can be applied to non-chromic acid copper and brass etch and bright dips, nitric acid strippers, aluminum bright dips and cation ion exchange regenerant. Chromates, very concentrated acids, and some hydrochloric acid processes are generally not good candidates for this technology.

Costs

Capital costs range from $30,000 to $40,000 for capacities under 200 grams/hour up to over $100,000 for capacities in the range of 1 kilogram per hour. Larger units are also manufactured. Little data are available on operating costs but they consist of labor, electricity, parts, and resin replacement.

4.6.4 Ion Transfer

Ion transfer unit consists of one or several membrane compartments which separate the cathode from the anode of an electrolytic cell. The membrane is usually a porous ceramic pot and the cathode is contained within the pot while the anode surrounds it. Alternately, the membrane may be constructed of polyfluorocarbon material and the catholyte compartment is re-enforced with polyethylene. The anode is in direct contact with the process fluid, while the cathode is separated from the process fluid by the membrane.

Small in-tank units often use the process rectifier and operate only while parts are being plated. These units must be removed when the rectifier is switched off because the membrane will leak cations back into the process tank. When current is flowing through the cell, cations in the process fluid are driven through the pores in the membrane and precipitate in the cathode compartment, plate onto the cathode, or remain in solution in the catholyte. The catholyte is initially made up as chromic acid, and usually taken directly from the bath. The efficiency of the cell gradually falls as Cr^{+6} is reduced to Cr^{+3} in the catholyte and tramp metals rise in concentration. The catholyte is replaced at regular intervals, usually ranging from several hours to several days, depending on the concentration of cations in the bath and the volume of the catholyte. Automated units will replenish the catholyte with fresh fluid at regular intervals. Catholyte volume usually ranges from only 5 to 10 liters or less in a single cell unit to 50 or more liters in a large, multi-cell unit. The anodic oxidation of Cr^{+3} to Cr^{+6} has the effect of lowering the overall Cr^{+3} concentration in the bath.

Cation removal rates are determined by the membrane area, the amperage applied to the cell, and the concentration of cations in the process fluid. Small units remove on the order of 10 to 50 grams of cations per day, whereas a multi-cell unit can remove up to 1,000 grams or more per day. Generally, removal rates fall sharply as the concentration of cations in the process fluid falls below 3 grams per liter. Cr^{+3} oxidation rates are determined by the anode area and the amperage applied to the cell and also range from a few to several hundred grams per day. Units are sized to remove cations at a rate near or somewhat faster than the introduction rate.

Applications and Restrictions

Because of the relatively low cation removal rates, this technology is best suited to maintaining relatively clean baths rather than attempting to clean highly contaminated ones. Tramp metal concentrations of 4 grams per liter can be achieved with this technology. Achieving lower concentrations, if possible at all, will result in higher energy costs and an increase in the volume of waste catholyte produced. The waste catholyte contains some chromium which is lost during catholyte changes.

Aluminum and other cation removal from chromic acid etch or anodizing solutions has been accomplished with this technology, though applications other than chrome plating baths are relatively rare. In etch solutions, the introduction rate is quite high and a multi-celled external unit is required.

Costs

In-tank ceramic pot styles that operate off of the tank rectifier can be purchased for $1,000 or less. External units with 400 grams per day removal capacity cost $30,000 or more depending on automation and instrumentation. Operating costs consist of electricity, labor, and membrane or pot replacement. Membrane life is several years. Ceramic pot life is also several years, but the pots can be broken during cleaning and handling. Labor associated with cleaning can be considerable. Manual systems require frequent catholyte changes and cleaning of the pot is usually performed during these changes. Sludge build-up in the catholyte creates the need for frequent clean outs that can require considerable effort. Savings result from extended bath life which reduces chemistry usage and waste production.

4.7 Chemical Recovery Technologies

4.7.1 Atmospheric Evaporation

Most atmospheric evaporators use a forced air system. These units consist of a heater to pre-heat the fluid being evaporated (in most cases, this is the process or evaporation tank's heating system), a pump to transfer the fluid to the evaporation chamber, a blower that provides a source of non-saturated air to the evaporation chamber, and the chamber itself, which consists of fins or a packing surface to increase the surface area of the air-fluid interface. Evaporation rates are dependant on the size of the chamber, the solution temperature, and the temperature and humidity of the air blown across the chamber. The solution being evaporated must be heated to a minimum of 29°C, below which evaporation rates are inefficient. Commercial units with evaporation rates from 40 to 340 liters per hour are available with most units designed for less than 150 liters per hour. Construction usually consists of polyethylene but specialty evaporators are made from materials specific to the application. For example, high temperature PVDF units can operate on fluids heated up to 82°C.

Applications and Restrictions

Atmospheric evaporators are found on a wide variety of processes, including nickel plating, chrome plating, and acid zinc plating. They are commonly applied to a heated process bath to increase its evaporation rate to make headroom for the direct return of an associated recovery rinse system. The rinse system is usually a multi-stage counter-flowing rinse that flows directly into the bath. Its flow rate is adjusted to equal the surface evaporation of the bath plus the evaporation rate achieved by the evaporator. For lower temperature process baths, the rinse water exiting the counterflowing series is directed to an offline tank where it is heated and circulated through the evaporator. Most of the flow is evaporated, and the concentrated fluid in the off-line tank is returned to the process bath at a rate equal to its evaporation and drag-out rate. Ambient temperature baths require a similar configuration, but some process fluid must be circulated to the off-line tank and evaporator to create headroom in the process tank.

Process fluids that degrade with heat are not appropriate for atmospheric evaporation. Most efficient are fluids, such as nickel plating baths, which are already heated to approximately 49°C to 65°C, making the energy requirements small. A disadvantage of evaporation-based recovery is that all drag-out, including unwanted components are returned and accumulate in the process tank. De-ionized water is necessary as rinse water to prevent the introduction of new contaminants. Also, solutions degraded by aeration, such as cyanide or tin plating baths, are not candidates for atmospheric evaporation.

Costs

Capital costs vary depending on several factors, including the unit's processing capacity. A Typical atmospheric evaporator that can process 40 to 75 liters per hour costs less than $10,000. Installation costs can be significant because plumbing and duct modifications may be necessary. Operating costs (i.e., electricity and labor) average $0.25 to $0.35 per gallon ($0.07 to $0.09 per liter).

4.7.2 Vacuum Evaporators

Vacuum evaporators take advantage of the boiling point depression of water as air pressure decreases. In practice, pre-heated fluid is pumped into the vacuum chamber where it quickly vaporizes. Because of the boiling point depression at low pressures, high evaporation rates can be achieved at temperatures considerably lower than those required for atmospheric evaporators. The vapor can be discharged to the atmosphere or distilled and re-used. Types of vacuum evaporators include thin film, flash, and mechanical vapor recompression. Thin film evaporators operate by distributing an extremely thin film of fluid across the heat exchanger surface. Rising film, falling film and wiped film evaporators are variations of this basic type and offer different advantages for specific applications. With flash evaporators, appropriate for concentrated or calcium-rich streams, the liquor flashes as it enters the vacuum chamber, causing crystallization and creating a slurry. Other designs which limit or eliminate the need for steam or other heat source include a heat-pump type, which employs a refrigerant and compressor to provide and reuse heat for evaporation, and mechanical vapor recompression, which captures and re-uses the heat released during condensation. Mechanical vapor recompression evaporators are the most expensive but most efficient type.

Applications and Restrictions

Vacuum evaporators are typically used in applications where atmospheric evaporators are not practical. Operating energy expenses favor the selection of vacuum evaporators when rates of 190 to 265 liters per hour or more are required. Vacuum evaporators require less heating and aeration, making them the choice for fluids that are technically incompatible with atmospheric evaporators. Vacuum evaporators provide a major advantage when they are configured to re-use the condensate as rinse water and return the concentration to the process bath in a closed-loop.

A typical configuration is a multi-staged counter-flowing rinse which discharges to the vacuum evaporator. The condensate, which is 90 to 95 percent of the feed flow, is returned to the last stage of the counterflowing series, and the loss is made up with a small de-ionized water stream. The condensate is returned to the bath. This arrangement assumes a moderately heated bath that has an evaporative loss equal to 5 to 10 percent of the rinse flow. If the bath has no appreciable evaporative loss, a small volume of the bath must be passed through the evaporator along with the rinse flow to create some headroom for return.

Neither type of evaporator is able to compete with ion exchange or reverse osmosis for recovery of large flow volumes of dilute rinse water.

Costs

The capital costs for vacuum evaporators ranges from $125,000 to $175,000 (for units processing 760 liters per hour). Operating costs are lower than those for atmospheric evaporators averaging $0.05 to $0.12 per gallons ($0.01 to $0.03 per liter). Repair costs for vacuum evaporators are reportedly higher than those for atmospheric evaporators.

4.7.3 Ion Exchange

Ion exchange refers to chemical reactions that occur at exchange sites on the surface of an ion exchange resin. Cation resins exchange hydrogen ions for cations in the stream; anion resins exchange hydroxyl ions for other anions. The reaction is reversible and the resin is regenerated by passing an acid through the cation column or a base through the anion column, which strips the captured ions and returns the resins to their initial states. The ions removed from the rinse stream are concentrated in the spent regenerants. Several selective cation resins, often referred to as metal scavenging or metal polishing resins, have been developed that preferentially exchange for only multi-valent cations, such as copper, nickel, or lead, and do not exchange for common monovalent cations such as potassium and sodium.

The basic unit of ion exchange equipment is the vessel, or column, which contains the ion exchange resin. Rinse water is pumped through the column where it contacts and reacts with the resin. The equipment may consist of a single column or several columns in series depending on the flow rate and type of resin. Columns range in size from 28 to over 300 liters of resin capacity. Typically, a minimum of 30 liters of resin is required for every 7 to 10 liters per minute of flow. The capacity of ion exchange resin is expressed in terms of ion equivalent (i.e., molecular weight divided by valence) per liter of resin.

Complete deionization of the wastestream requires at least two columns, one cation and one anion. If the operation cannot be suspended during regeneration, two like columns (i.e., two cation and two anion columns) are necessary to alternate the columns. Some manufacturers recommend three like columns since, in practice, columns begin leading ions before the resin's theoretical capacity has been reached. With two columns always on-line, leakage is captured by the second column and the first can remain in service until maximum capacity is reached.

Fully automatic units initiate regeneration based on accumulated flow volume, or more sophisticated methods such as metal ion detection, redirect the flow to a fresh column, and begin regeneration on the spent column. Semi-automatic units require operator-initiation of regeneration. Manual systems require pre-mixing of regenerant, manual valving, and fluid transport.

Applications and Restrictions

Ion exchange is applied in two basic configurations. De-ionizing installations completely remove all cations and anions from a relatively dilute rinse stream and recycle the de-ionized water back to the rinsing process. Generally, the total dissolved solids concentration of such streams must be below 500 mg/l, to maintain an efficient regeneration frequency. Since all of the process dragout is present in the regenerants, some processes will tolerate the direct return of the regenerant and a closed loop is set up. Usually, however, the regenerant is too dilute or incompatible with the process chemistry and it cannot be re-used. Recovery in these cases is performed by electrowinning. Aggressive conventional means of drag-out recovery including drag-out tanks and countercurrent rinsing are usually required or desirable to enhance the efficiency of the recovery process.

Metal scavenging installations recover only the metal portion of the drag-out. This arrangement is efficient if the metal ions being scavenged are the only regulated ions in the stream. In these cases, the stream can be discharged without further treatment. Scavenging can also be efficient in terms of resin capacity. The metal content of the stream may only be a small fraction of the total dissolved solids present in the stream, making scavenging suitable over a wider range of TDS. Scavenging also provides a very metal-rich regenerant, particularly suitable for electrowinning. Water recycling is not possible since only a portion of the cations and none of the anions are removed. Effluent metal concentrations of under 0.5 mg/l are typically achieved with standard installations. Scavenging resin systems can also be used to polish discharge from a conventional waste treatment system that is unable to remain consistently in compliance. The offending ion or ions are selectively captured by the resin but the non-regulated, concentrated salts used for pH neutralization pass through. The regenerant may be sent to an electrowinner to recover metal, or returned back upstream to the conventional waste treatment system.

Either configuration may be employed on a mixed stream from two or more processes or installed as an end-of-pipe treatment for an entire plating room. With such arrangements, no direct return of the drag-out is possible and the regenerant will contain two or more different metal ions. Recovery is again performed by electrowinning. Filtration and pretreatment of the feed stream may be necessary. Many resins are sensitive to organic molecules and carbon filtration is often required prior to ion exchange.

Deciding which configuration is most advantageous in a particular shop depends upon the nature of the processes present, the possibility of returning the regenerant to the process tank, the cost of water, cost of the equipment and (often more importantly) installation, and the need to limit discharge volume. Mixed streams require careful characterization; estimates of flow volumes and concentrations become more difficult to make as the number of sources increase. Many streams are not efficiently mixed. Streams containing lead or gold, for example, are not usually mixed with streams containing metal ions such as copper or nickel due to different regeneration methods or chemistries.

Many processes are excellent candidates for ion exchange. Successful applications include the rinse water from plating processes of copper, cadmium, gold, lead, nickel, tin, tin-lead, and zinc. Gold-bearing resins are frequently incinerated and the gold content recovered. Lead is also difficult to recover from ion exchange resins; only methane sulfonic acid (very expensive) and flouboric acid (usually not suitable for electrowinning) are effective regenerants, and these resins may be replaced when exhausted rather than ever regenerated. Cyanide bath rinse waters can be ion exchanged; cation resins are capable of breaking the metal-cyanide complex and the cyanide is removed in the anion column. The cation regenerant can be electrowinned, and the cyanide present in the anion regenerant can be returned to the process or destroyed conventionally.

Costs

Capital costs depend on the volume of flow being serviced and the level of automation required. A third capital cost factor, frequently overlooked, are the installation costs, which may be considerable in certain applications. Small, manual units, applied to flows of 20 liters per minute or less, may be purchased and installed for less than $15,000. A fully automatic, 75 liter per minute unit, with an integrated electrowinner, will cost approximately $75,000 with installation.

Operation and maintenance costs are generally low. A major expense is resin replacement which can be quite expensive. Resin should, however, be expected to last for 3 years or more. Resin costs range from $7 to over $22 per liter. Labor costs are dependant on the level of automation included with the unit and can range from over $1 per 1,000 liters for manual or undersized installations to less than $0.25 per thousand liters for fully automatic systems. Upstream components, such as sand, polypropylene and carbon filters also contribute to operational costs.

4.7.4 Electrowinning

An electrowinning unit consists of a main vessel or tank, which houses a number of electrodes, a rectifier to provide a direct current source, and the pumps and plumbing necessary to transport the fluid being treated to and from its source. Fluid is pumped from a reservoir or drag-out tank to the main tank where it flows through or around the charged electrodes and then is caused, usually by gravity, to return to the reservoir. While in the main tank, positively charged metal ions are attracted to and reduced to metal form on the negatively charged cathode. Most anodic reactions are of little interest with the exception of cyanide oxidation to cyanate, which is an important benefit of electrowinning cyanide-bearing drag-out or spent process fluids.

A variety of cathode designs are available, the choice of which depends mostly on the concentration of metal in the electrolyte and the preferred form of recovered metal. The three most common are flat sheet, wire mesh, and reticulated designs. Flat plate cathodes are used with high metal concentrations. Below 1,000 mg/l of metal ions, they present poor plating efficiency due to their low surface area. For high metal concentrations, they are usually the design of choice because the plated metal can be easily removed by mechanical means (scraping or peeling) and the cathodes can be reused. Wire mesh cathodes offer a greater surface area than flat plate cathodes of the same dimensions and can be used with lower metal concentrations than flat plate types. However, metal deposited onto the wire mesh must be chemically stripped. Typically, the wire mesh cathodes are used as anode material in an applicable plating tank. The reticulate cathodes offer the greatest surface area per square meter of material. They are used mostly for low to moderate concentrations of metal and can be effective below 10 mg/l of metal ions. The reticulate cathodes are not reusable and are typically sent directly to scrap dealers.

Anodes are usually wire-mesh, and constructed of various metals, typically stainless steel or titanium. Some manufactures offer low-cost graphite anodes. For oxidizing electrolytes (e.g., persulfates, nitric acid-based solutions, or fluoborates), platinum-coated titanium along with other, proprietary rare-earth oxide coatings are available. While cathodes are generally inexpensive, anodes can represent a significant percentage of the unit's entire purchase price.

Cathodes and anodes are closely spaced, usually less than one inch apart. Both sides of each cathode directly faces an anode, thus units will have one more anode than cathode. During operation, the concentration of metal ions can be depleted in the vicinity of the cathodes. This effect is countered by designs that include a high fluid flow past the electrodes and a means of agitation, such as air sparging.

The capacity of an electrowinning unit can be expressed in terms of cathode area, maximum rectifier output (in amperes), or metal recovery rate (such as pounds of metal plated per day) and all these quantities are inter-related. Since electrowinning is operated in a window of optimum current density (expressed in amps per square foot of cathode area), the size of the rectifier must be matched to the number and size of the cathodes. Manufacturers design units with enough cathode area so that the window of optimum current density is not exceeded when the rectifier operates at or near maximum output. Commercially available units range from 0.2 m^2 or less of cathode area to well over 10 m^2 and rectifiers range from less than 100 amperes maximum output to over 2,000 amperes. The recovery rate is largely dependant on the concentration of metal ions in the electrolyte being electrowinned. The theoretical maximum plating rate is governed by Faraday's law and ranges from 1.19 grams/amp-hour for copper to 7.35 grams/amp-hour for gold. Units equipped with reticulated cathodes and operating on electrolytes containing several grams/liter of metal ion concentration may approach the theoretical maximum plating rate. At concentrations below 100 mg/l, the plating rate will fall dramatically to below 10 percent of the theoretical maximum in most cases.

Applications and Restrictions

The unit must be sized to have a metal removal rate equal or greater than that of the metal introduction rate into the drag-out tank. The electrowinning unit will cause the metal concentration of the drag-out tank to average much lower than before; rising briefly immediately after a drag-out event, then falling gradually until additional parts are rinsed. The resulting low average metal concentration leads to a considerably lower mass of metal entering and being discharged from the flowing rinses. Typically, a drag-out tank may be maintained below 100 mg/l of metal concentration.

The application of electrowinning to a drag-out tank usually precludes the direct return of the drag-out to the process tank due not only to the metal depletion but also to possible chemistry-altering anodic reactions. Also, other (non-metal) constituents build in concentration and may eventually force disposal of the fluid.

In many cases, ion exchange regenerant from a cation resin column is suitable for electrowinning. It may contain several grams per liter of mixed heavy metals that are readily plated. A batch spent regenerant is pumped to a reservoir near the electrowinner and circulated through the unit until the desired concentration is reached. In some cases, electrowinning is allowed to proceed until the metal concentration reaches compliance levels and the electrolyte is discharged. This is possible only when the metal ions being plated out of the solution are the only regulated ions present. Furthermore, the plating rate will drop dramatically as the concentration of metal ions falls below 100 mg/l. It may take much longer for the electrolyte to drop from 100 mg/l to 1 mg/l than from 10 g/l to 1 g/l. Usually, the desired concentration is near 100 mg/l and when reached, the fluid is sent to conventional treatment or adjusted and re-used as fresh regenerant.

Strongly oxidizing substances such as nitric acid or flouboric acid are generally not good candidates for electrowinning due primarily to the very short life of the anodes in such environments. Hydrochloric acid or other compounds containing the chloride ion may present the problem of chlorine gas evolution at the anodes.

Costs

In general, the capital costs of electrowinning equipment are low. A unit equipped with a 100 ampere rectifier and 0.2 m^2 of cathode area may carry a purchase price of between $8,000 and $15,000, depending largely on the type of anodes and cathodes. Such a unit may remove up to 500 grams of metal per day from a drag-out tank.

Significant operating cost components are electricity, electrode replacement and operating and maintenance labor. Electricity costs per unit mass of metal recovered varies with the concentration of metal in the electrolyte. Low concentration of metal ions leads to lower efficiency to higher costs for electricity. Flat plate steel cathodes are re-used after being scraped free of metal deposits and are therefore rarely replaced. Wire mesh and reticulate cathodes usually are rated to hold more than 1 kilogram of metal and generally cost less than $100/$m^2$. Anodes vary widely in cost, from $600/$m^2$ to more than $3,000/$m^2$ for platinum coated-titanium types. Anodes require replacement every 1 to 5 years depending on the nature of the electrolytes being electrowinned. Labor costs are low. Besides daily checks for electrical settings and overall operation, many installations require little scheduled attention.

4.7.5 Electrodialysis

The feed stream entering an electrodialysis unit is split into two streams, a concentrate and a diluate. This is accomplished by a stack of selective membranes, across which is applied a direct current. The membranes in the stack are alternately cation- and anion-specific. Between the membranes in the stack are compartments, which alternately consist of concentrate or diluate. The feed stream is pumped into the diluate compartments. Cations in one diluate compartment traverse one cation-specific membrane in the direction of the cathode but are trapped in that compartment by the next membrane which is anion-specific. Anions from the neighboring diluate compartment traverse the anion membrane in the direction of the anode, joining the cations, and are likewise trapped by the next cation-specific membrane. In this way, the diluate is further diluted of ions, and in each concentrate compartment, both anions and cations are trapped. The concentrate is perhaps 10 times more concentrated than the feed stream, but is usually not as concentrated as the process bath.

Capacity is determined by the stack size, or membrane area, and the rectifier. The unit must be sized to capture the drag-out from the diluate to the concentrate at the rate at which it is being introduced into the rinse water. Under-sized units will result in a greater residual concentration remaining in the diluate, which is usually discharged for conventional treatment. Most units are custom-sized for each application and range from less than 1 m^2 to well over 10 m^2 of membrane area.

Applications and Restrictions

For electrodialysis to offer any advantage over competing technologies, the process fluid must tolerate the direct return of the concentrate. Since the concentrate is usually less concentrated than the bath itself, only heated fluids with some evaporative headroom are candidates. Manufacturers have described applications recovering the drag-out from Watts nickel, copper cyanide, cadmium cyanide and zinc phosphate.

If the feed stream is from a drag-out rinse, the diluate may be re-used and pumped back to the drag-out tank. In this configuration, the technology competes with electrowinning. Although more expensive, unlike electrowinning, the dragout recovered is returned to the process tank and process chemistry does not rapidly accumulate in the drag-out tank.

Costs

Capital costs are related to membrane surface area or to feed flow volume and characterization. Most units are customized to a particular application. In general, the technology is more expensive than other recovery technologies. Units range from $75,000 for 20 ft^2 of membrane area to several hundred thousand for units of 150 ft^2. For Watts nickel, a 20 ft^2 unit would be expected to have a capacity of 0.5 to 1 gallon of drag-out recovery per hour. Little information is available on operational and maintenance costs, but they are known to consist of membrane replacement, electricity and labor.

4.7.6 Reverse Osmosis

The basic component of reverse osmosis equipment is the membrane, which may be tubular, hollow fiber, or spiral wound. The feed stream is pumped continuously into the membrane-containing vessel where it flows parallel to the membrane surface, unlike conventional filtration, where the filtering substance is positioned as a barrier to the flow. Under pressures of up to 1,000 pig, relatively pure water is forced through the membrane, while dissolved solids are chemically repulsed. Suspended solids are larger than the membrane's pore size and cannot cross. The membrane rejection rate, or the portion of the feed stream's dissolved solids unable to cross the membrane, is less than 99 percent of multi-valent ions and 90 to 94 percent of mono-valent ions such as sodium or chloride. Because a portion of the mono-valent ions in the feed stream manage to cross the membrane, the permeate is of lower purity than the effluent of common ion exchange equipment in terms of conductivity. Metal and other ions of regulatory interest have very high rejection rates.

The concentrate stream from standard reverse osmosis equipment is usually no higher than 20 g/l TDS. Higher concentrations can be achieved by adding "stages," or additional membrane vessels. The concentrate from stage one is sent to stage two and so on. Concentrates approaching process bath concentrations are possible with multi-stage units.

The flow volume handled by a unit is dependent on several inter-related factors. Generally, capacity is increased by increasing the surface area of the membrane. If the feed flow is increased without a corresponding increase in membrane surface area, the volume of permeate and the concentration of the concentrate drops. Operation at higher pressures will increase the permeate volume. Capacity is therefore determined by the membrane surface area, operating pressure, and the requirements of the application.

Reverse osmosis equipment does not require the automation of other technologies due to the facts that it runs essentially in one mode at all times and electricity is not involved in the fluid separation. Units may include instrumentation that indicate the condition of the membrane by measuring the flux, or permeate flow per unit area of membrane. If the membrane fouls or clogs, the flux rate will drop and membrane replacement will be necessary. Pressure and other flow gauges are common.

Pre-filtration and pre-treatment of the feed stream may be necessary in some applications to lengthen membrane life or reduce the frequency of fouling. Filtration to remove suspended solids is usually necessary. pH adjustment may prevent precipitation from occurring as the feed stream is concentrated, but it may make the concentrate unfit for return to the plating bath.

Applications and Restrictions

Reverse osmosis is commonly applied to nickel plating processes. The feed stream is typically a series of counter-flowing rinses. The permeate is returned to the rinses and the concentrate is returned to the nickel bath. Fluid balances must be maintained. The permeate will be 2 to 10 percent less volume than the feed stream and a steady supply of city water must enter the counterflowing rinses to balance this loss. The concentrate flow entering the nickel plating bath replaces evaporative loss, but the two are precisely balanced. A storage tank for concentrate may be necessary, or, if the loss is greater than the concentrate flow, other means of replenishment may be required. For heated baths with considerable evaporation, the concentration of the concentrate can be significantly below that of the bath. If the concentrate is replacing drag-out from a ambient bath, it must be near the same concentration as the bath. Considerable engineering and customization is required for each application.

Other successful applications described by equipment manufacturers include zinc, cadmium and copper cyanides and non-cyanide zinc. For some applications, no attempt to return the concentrate to the process bath is made and recovery, if any, is done by another technology such as electrowinning.

Mixed stream and end-of-pipe after precipitation configurations also exist. Mixed-stream applications, not unlike those employing ion exchange, require alternate recovery technologies, usually electrowinning. End-of-pipe installations provide the benefit of recycling water that is otherwise discharged due to high concentrations of salts used for pH neutralization. The concentrate is discharged (some care must be taken to ensure that the concentrate remains below compliance levels where concentration-based discharge limit exist; concentrations 20 times that of the feed stream are typical) and the diluate is distributed to various rinsing operations.

Costs

Since flux rates vary from application to application and customization and special engineering can be necessary, cost estimates based simply on flow or flux volume are very rough. Reverse osmosis units start at $50,000 to $75,000 for flow rates of 75 liters per minute or less to over $300,000 for flows of 800 liters per minute. Operating cost components are labor, energy and membrane replacement.

5.0 Tools for Evaluating Pollution Prevention Opportunities

5.1 Cost Analysis

Industry has been slow to invest in pollution prevention projects in part because traditional investment review tools do not account for the true cost and environmental savings from pollution prevention. For most businesses, including the metal plating industry, gauging economic performance has been the underpinning of the investment review process. Unfortunately, traditional economic analyses have minimized or ignored the economic benefits of pollution prevention investments by either incorporating too few cost areas in the analysis of by examining costs over a too short period of time. Pollution prevention investments must be able to stand up to every other funding request to effectively compete for funding.

The following sections discuss how to expand upon traditional economic analysis to identify all costs associated with a particular operation or process at a facility. The approach is designed to allow managers to incrementally expand their traditional economic analysis framework, adding new cost elements to their existing modeling, as appropriate, given available resources. This approach gives flexibility to the economic analysis process and allows each analysis to be tailored in scope and detail to reflect both available data and specific investment review needs. Furthermore, basic cost data already embedded in existing facility-level models can be used to minimize the effort needed to secure required data.

The following sections first discuss how to expand upon traditional investment analysis procedures to more accurately reflect the true economic costs and benefits of investing in pollution prevention. Next, step-by-step instructions and a cost analysis worksheet are provided using these new concepts. Together, this discussion will provide the framework necessary to begin using economic analysis principles to evaluate the investment viability of pollution prevention projects.

5.1.1 Traditional Accounting/Budgeting Approaches

Economic analysis involves tabulating the financial costs and benefits that a project is expected to generate. These estimates provide the data necessary to evaluate the economic advantages of competing projects.

The easiest and most common economic evaluation is one that compares the up-front purchase price of competing investment alternatives. However, experience has shown that the up-front purchase price is a poor measure of a project's total cost. Costs such as those associated with maintainability, reliability, disposal/salvage value, and training/education must also be weighted in the financial decision-making process. Not surprisingly, methods to improve economic justification for pollution prevention investments involve addressing these shortcomings.

5.1.2 Ways To Improve Cost Analysis

<u>Expanding Cost Inventories</u>

For pollution prevention investments to compete fairly with pollution control and other investments, all potential costs and savings must be considered. In addition to including direct costs, a cost inventory should also include indirect costs, liability costs, and less tangible benefits. **Exhibit 5-1** lists many of the categories that can be used to accurately determine the financial costs associated with a particular investment opportunity.

The challenge for any manager seeking to use an expanded cost inventory for investment analysis is that all of the costs associated with a particular piece of equipment or process may be difficult to identify. Quantifying these costs may be a challenge because they may be grouped with other cost items in existing overhead accounts. For example waste disposal costs of current processes are often placed into a facility overhead account, whereas an expanded cost inventory would require these costs to be directly allocated to the product or process that produces them. Consequently, it is not expected that information for all the cost categories will be easily identified. Environmental managers should use this list of categories to help incrementally expand their existing financial analyses whenever possible.

<u>Expanding Time Horizons</u>

In addition to a more comprehensive cost inventory, a second concept that is helpful in uncovering the true economic benefits of pollution prevention investments is a longer time horizon, usually five or more years. This is because many of the costs and savings from pollution prevention take years to materialize, or because the savings occur each and every year for an extended period of time. For example, some pollution prevention investments may result in a significantly decreased liability risk in the future. Others may result in recurrent savings as a result of less wastes needing to be managed and disposed of every year. Conventional project analysis,

Exhibit 5-1. Cost Categories

Direct Costs

- Capital expenditures
  - buildings
  - equipment
  - utility connections
  - equipment installation
  - project engineering
- Operational and maintenance expenses
  - raw materials
  - labor
  - waste disposal
  - utilities: energy, water, sewerage

Liability Costs

- Penalties and fines
- Personal injury and property damage

Indirect Costs

- Compliance costs
  - permitting
  - reporting
  - monitoring
  - manifesting
  - record keeping
  - insurance
  - on-site waste management
  - operation of on-site pollution control equipment

Less Tangible Benefits

- Increased revenue from enhanced product quality
- Enhanced community and product image
- Avoided future regulatory costs
- Reduced health maintenance and absenteeism costs from improved employee health
- Increased productivity from improved employee relations

however, often confines costs and savings to a three to five year time period. Using this traditional time frame in project evaluation will lose track of many costs and benefits that pollution prevention options are designed to produce.

Managers of metal plating facilities in the developing world seeking to justify investments in pollution prevention on the basis of costs face challenges due to the comparatively low current costs associated with hazardous waste disposal and regulatory compliance. In these cases, expanding the time horizon for the investment analysis may allow managers to realistically project increased cost savings that will occur as a result of future regulatory and waste disposal infrastructure improvements.

Definitions and Terms

Over the last few years, researchers and managers working to promote pollution prevention have been developing ways to evaluate investments that account for the economic benefits of pollution prevention. Various systems and models have been developed, and numerous terms are currently used to define these systems. These systems and models all involve expanding traditional investment evaluation methods to address the issues stated above. For the sake of clarity, the following section provides a short description of the three most common approaches. These definitions were developed by the United States Environmental Protection Agency (USEPA). Managers may be familiar with these approaches, yet call them by a different name.

> The U.S. Postal Service is currently piloting the use of TCA to justify pollution prevention project at the facility level. The pilot study involves using a computerized spreadsheet to help track costs and measure performance.

Total Cost Assessment. Total Cost Assessment (TCA) refers to the long-term, comprehensive analysis of the full range of costs and savings of an investment that are or would be experienced directly by the organizations making or contemplating the investment.

Activity-Based Costing. Activity-Based Costing (ABC) is a process in which all environmental costs incurred by an organization, both direct and indirect, are allocated to the products or processes which generate them. Many of these costs are traditionally allocated to facility or corporate overhead accounts. By applying them directly to processes or products, managers can gain a more accurate picture of the true costs associated with manufacturing operations.

Life Cycle Costing. Life Cycle Costing (LCC) is a method in which all costs are identified with a product, process, or activity throughout its lifetime, from raw material acquisition to disposal, regardless of whether these costs are borne by the organization making the investment, other organizations, or society as a whole.

Evaluating Financial Performance

While expanding cost inventories and time horizons greatly enhance the ability to accurately portray the economic consequences of a single pollution prevention investment, financial performance indicators are needed to allow comparisons to be made between competing investment alternatives. Three financial performance indicators are currently in widespread use. The simplest approach is to conduct a payback analysis estimating the amount of time it will take to recover the funds expended on capital projects. The other approaches, net present value and internal rate of return, use the concept of the time value of money. These approaches are advocated by many economists as more accurate ways to evaluate investments, including environmental projects. Each of these techniques offer specific advantages and drawbacks for facility environmental managers.

Payback Period. Payback period analysis is the investment performance indicator used historically by many federal agencies. The purpose of a payback analysis is to determine the length of time it will take before the costs of a new investment are recouped. For example:

$$\text{Payback Period (in years)} = \frac{\text{start up costs}}{\text{annual benefits} - \text{annual costs}}$$

$$\text{Payback} = \frac{\$800}{\$600 - \$400} = 4 \text{ years}$$

Those investments that recoup their costs before a set "threshold" period of time (usually 3-5 years) are determined to be investments worth funding. Payback period analysis does not discount costs and savings occurring in future years. In addition, costs and savings are not considered if they occur in years later than the threshold time in which an investment must pay back its costs in order to be funded.

> Many private sector companies and some government agencies currently use NPV to analyze financial performance of environmental investments.
>
> Hyde Tools Company used NPV analysis to document over $15,000 in benefits from a pollution prevention project that involved a rinse water recycling project.
>
> Tektronix Corporation used NPV calculations to document over $90,000 in benefits from a process modification to its painting system that

Net Present Value. The Net Present Value (NPV) method is based upon the concept that a dollar today is worth more than a dollar in the future (commonly referred to as the time value of money). Specifically, this method discounts the value of future costs and revenues (i.e., cash flows). These discounted cash flows are then added together to calculate the "Net Present Value" of the investment. This method is particularly useful when comparing pollution prevention investments against alternatives that result in higher annual waste management and disposal costs. The increased costs of current operations or of investment options that do not reduce wastes will tend to lower the net present value of these options. Also, this method easily accommodates the use of an expanded cost inventory when calculating all costs and benefits.

Discounted savings - discounted costs = NPV

$300,000 discounted savings
- $200,000 discounted costs
= $100,000

Internal Rate of Return. The Internal Rate of Return (IRR) method is a method that calculates the rate at which a stream of cash flows must be discounted so that the present value of the cash flows is equal to the initial investment. Organizations using the IRR method to evaluate investment options specify a "cutoff rate" (sometimes referred to as a "hurdle rate"). Projects are pursued if the internal rates of return exceed the cutoff rate and are rejected if the internal rates of return fall below the cutoff rate.

5.1.3 Application Of Improved Cost Analysis To The Metal Plating Operations

Investments in pollution prevention in the metal plating industry can result in significant cost savings, if the investment analysis process is sufficiently comprehensive. **Exhibit 5-2** identifies areas of significant potential cost savings resulting from the use of pollution prevention strategies identified in Chapter 3.

5.1.4 Overcoming Existing Challenges

Businesses that have begun to implement the investment review methodologies discussed within this chapter have encountered challenges that required the development of innovative solutions. The following section highlights some of the challenges facilities have encountered and discusses possible solutions.

<u>Proper Allocation of Cost Categories</u>

Compared with the traditional investment analysis processes, expanding the analysis to include broader cost inventories requires a more detailed data tracking system. Currently, many organizations utilize tracking systems that will group together many cost categories into facility-wide overhead accounts. These types of tracking methods make it very difficult to identify all of the discreet costs that will be impacted by proposed investment alternatives. Pollution prevention activities in particular are at a disadvantage because many of the savings that result from these

Exhibit 5-2. Cost Savings from Metal Plating Waste Minimization

Product Changes	Cost Impacts
<u>Description</u>	
Environmentally Friendly Product Design - reduce or eliminate coating requirements - include drain holes in product	• longer product life • reduced coating material purchases • reduced chemical purchases • reduced water use • reduced dragout/rinse water • reduced use of treatment reagents • reduced treatment sludge • lower hazardous waste management and disposal costs • lower compliance costs
Input Material Changes	
<u>Description</u>	
Reduce or Replace Chlorinated Solvents Reduce or Replace Cyanide Reduce or Replace Cadmium Reduce or Replace Chromium	• reduced use of treatment reagents • reduced treatment sludge • lower hazardous waste management and disposal costs • lower compliance costs
Process Changes	
<u>Description</u>	
Vacuum Deposition to replace cadmium or chromium plating	• very high capital costs • reduced chemical purchases • reduced water use • reduced drag out/rinse water • reduced use of treatment reagents • reduced treatment sludge • lower hazardous waste management and disposal costs • lower compliance costs
Thermal Spray coatings to replace hard chromium plating	• longer product life • lower compliance costs
Chemical Vapor Deposition	• capital and operating cost increased to control air emissions • reduced chemical purchases • reduced water use • reduced drag out/rinse water • reduced use of treatment reagents • reduced treatment sludge • lower hazardous waste management and disposal costs • lower compliance costs • reduced potential liability
Ion Implantation	• longer product life • reduced potential liability

Exhibit 5-2. Cost Savings from Metal Plating Waste Minimization (Continued)

Product Changes	Cost Impacts
Maintenance Methods	
Conventional Maintenance Methods	
– Filtration of suspended solids to remove contaminants from the baths solutions and reduce frequency of dumping concentrated chemicals into baths – Carbon treatment – Carbonate freezing (lowering the temperature of cyanide baths)	• reduced Chemical Purchases • reduced use of treatment reagents • reduced treatment sludge • lower hazardous waste management and disposal costs • fewer product rejects
Advanced Maintenance Methods	
– Microfiltration – Ion Transfer (chrome baths) – Membrane Electrolysis – Ion Exchange (chrome baths) – Acid Sorption (anodizing solutions) – Process Monitoring and Control	• reduced processing time • extended bathlife • improved product quality • less processing time
General Waste Reduction Practices	
Description	
Drag Out Reduction	• Reduced water use • Reduced rinse water • Reduced use of treatment reagents • Reduced treatment sludge • Lower hazardous waste management and disposal costs
Rinse Water Reduction	• Reduced use of treatment reagents
Chemical Recovery Technologies	
Evaporation Ion Exchange Electrowinning Electrodialysis Reverse Osmosis	• Reduced chemical purchases • Reduced water use • Reduced use of treatment reagents • Reduced treatment sludge • Lower hazardous waste management and disposal costs • Lower compliance costs

investments (e.g., energy, sewage, water, permitting, and waste disposal) often occur in areas lumped into overhead accounts.

To overcome this, staff performing investment analyses must first identify the exact data needs for the project under review. Then, a comparison can be made to information available from traditional record keeping systems in order to identify information gaps resulting from items being lumped together or reported on a facility-wide basis. To eliminate the data gaps, one of several approaches can be employed:

- For the simplest of challenges where several inventory categories have been combined, a review of the input data developed by each department in a facility may reveal the data for the particular project in question. For example, while the accounting department indicates on its books only the total quantity of copier paper used at the entire facility, a review of department specific expenses may reveal a more detailed account of paper use by location.
- For categories that are aggregated for the whole facility and not by specific project (e.g., water usage), engineering estimates or a facility walk

through can often be used to generate an estimate allocation to specific projects.

- For aggregated categories that cannot be easily allocated on a project specific basis by either of the above two methods, it may be worthwhile to discuss the data needs both with the vendors that supplied the original equipment to see if any baseline consumption data exist and/or with auditing professionals to identify what types of measurement devices or meters could be located at the specific project to meet the data needs.

Placing Value on Future Costs and Benefits

Estimating future costs and benefits can become a difficult task for anyone conducting investment analyses. Quantitatively estimating future costs for items such as the decommissioning property clean-up and environmental compliance can be a very difficult task. A useful approach is to group future costs into one of two categories; recurring costs, or contingent costs.

Recurring costs include items that are currently occurring and are anticipated to continue into the foreseeable future based upon regulatory requirements. These include permits, monitoring costs, and compliance with regulatory requirements. The first step in estimating the future costs of these items is to determine what the facility is currently paying. Then estimate how much the cost can reasonably be expected to escalate in the future. For example, if monitoring costs are currently $100 and are expected to rise with inflation, a conservative estimate would be a 4-percent annual increase. Consequently, the monitoring costs a year from now would be estimated at $104, assuming that monitoring requirements do not become more stringent. Note, if using the enclosed worksheet, you do not have to escalate these values because the worksheet already takes inflation into account when calculating present values.

Contingent costs include those catastrophic future liabilities such as remediation and clean-up costs. While current activities can lead to these future costs, quantitative estimates of these liabilities are difficult to obtain. Quite often the only way to include these future liabilities in the budgeting process is to qualitatively describe estimated liabilities. without attempting to reduce these costs to a dollar amount. If a pollution prevention option is being considered, a comparison highlighting the areas in which future liability would be reduced by implementing the pollution prevention option should be included. An example of this approach could be used in describing the future benefit of switching from lead-based paint to water based paint. Most likely, the best option may be to fully describe the potential liability if the change is not made and, if possible, document the remediation cost that could result if a liability event was to occur today.

5.1.5 Getting Started

The concepts discussed above can be used to help identify, calculate, and demonstrate the economic benefits that result from investing in pollution prevention. They can be used to provide a fair and complete comparison of two or more competing investment alternatives, or can be used to compare proposed investments to the costs of continuing existing operation unchanged.

As discussed earlier, managers seeking to expand their existing economic analysis methods to better capture the benefits of pollution prevention should incorporate as much of the concepts discussed in this chapter as their particular situation allows. Managers who cannot isolate and quantify all of the items they have identified in their expanded cost inventory should nevertheless research and include cost data on all of the items for which they can collect reliable data. Similarly, the time horizon for the analysis should be extended as far as possible, given available data and the type of investment evaluation method in use at their facility. Incorporating these concepts is often an incremental process. Even small steps toward expanding inventories and extending time horizons can result in funding approval for pollution prevention investments that would otherwise face rejection.

A worksheet has been provided on the following page to assist in better analyzing the costs and benefits associated with environmentally-based investment options. The worksheet incorporates the concepts discussed in this chapter: capturing more cost categories by better allocating costs to specific activities and by expanding the cost areas included in the analysis; and expanding the time horizon over which competing investments are analyzed. The worksheet also provides for the ability to calculate two measures of financial performance, a simple payback analysis and a net present value calculation which incorporates the time value of money. Both of these calculations can help in making comparisons between competing investment options or in comparing a proposed investment against current operations.

The following instructions are designed to assist in completing the investment analysis worksheet. When completing the worksheet, do not worry if data are not available to complete all requested information. Even by just completing a few sections of the worksheet with data that otherwise would not

PROJECT ANALYSIS WORKSHEET

	Section		ESTIMATED CASH FLOW IN EACH YEAR										
			Start-Up	1	2	3	4	5	6	7	8	9	10
CASH OUTFLOWS	1	**CAPITAL COSTS**											
		Equipment											
		Utility Connections											
		Construction											
		Engineering											
		Training											
		Other											
		Subtotal Section 1											
	2	**OPERATING COSTS**											
		Materials											
		Labor											
		Utilities											
		Waste Mgmt.											
		Compliance											
		Liability											
		Other											
		Subtotal Section 2											
CASH INFLOWS	3	**REVENUES**											
		Sale of products											
		Sale of by-products											
		Sale of recyclables											
		Other											
		Subtotal Section 3											

4 **PAYBACK** ____ years Equals Section 1 divided by (Section 2 – Section 3) **NOTE, USE THE VALUES FROM THE SHADED BOXES ABOVE**

5 **CASHFLOW**

Cash flow is calculated by subtracting Cash Out\flows from Cash Inflows during each year of the investment (i.e,. Sec 3 – Sec 2 – Sec 1)

6 **CF × PV**

7 **NET PRESENT VALUE** ____ Equals the sum of all values in Section 7

have been collected, the information recorded will be useful in enhancing the accuracy in evaluating investment opportunities. Specific instructions follow:

Begin by determining the purpose of the analysis, the audience to whom it will be directed, the facility's decision making criteria, and the format in which the analysis must be presented. This information will be critical in ensuring that the scope of the analysis is appropriate, and that the completed analysis will be presented in a readily understood and accepted manner.

Sections 1-5. Identify the economic consequences associated with the activity under review. The specific items (i.e., cost categories) mentioned in the worksheet may not be a complete list of costs incurred at your facility, add new categories as appropriate. If you are conducting a payback analysis, completing information for only the initial year is acceptable provided that data are available to describe annual costs and annual savings. If you plan to analyze the financial performance of the investment using a NPV calculation, you need to estimate future costs and benefits.

To allow comparisons with other investment options or existing investment guidelines, two measures of economic performance are included in the worksheet. To conduct a payback analysis, refer to section 6. To conduct a net present value analysis, refer to sections 7 through 10.

Section 6. Complete section 6 if you wish to calculate the Payback Period of an investment. This section calculates the amount of years it will take to recoup the initial capital expenditure. This value is obtained by dividing the total capital expenditures to establish the project by the net annual benefits (e.g., obtained by subtracting the expected annual expenses from the expected annual revenues). If only a payback analysis is needed, skip the following steps.

Section 7. Complete sections 7 through 10 if you wish to calculate an investment's Net Present Value. For each year included in the evaluation, calculate the annual net cash flow by subtracting the capital expenditures (section 1) and annual expenses (subtotals from sections 3,4,5) from the annual revenues (section 2).

Section 8. To calculate the NPV requires determining the value of future cash flows today. To do this, present value factors are used to discount future cash flows. Typically, this percentage rate reflects the return the company could expect to get by investing its resources elsewhere (e.g., another project). If you do not know the rate used by your company, we recommend using 15 percent.

Section 9. Multiply the cash flows (section 7) by the PV factors (section 8) to determine the present value today of the cash flow in each year.

Section 10 (NPV). Sum all the annual discounted cash flows to determine the Net Present Value of the process. If the value is positive, the investment is cost-beneficial. If more than one investment is being analyzed, the investment with the greatest NPV is the most cost-beneficial.

After completing the analysis, write a narrative to accompany the investment analysis explaining the results of the analysis. Be sure to include a discussion of the economic benefits of the proposed pollution prevention investments that were not able to be quantified, and a discussion of the non-economic benefits that may tip the scales in favor of the pollution prevention estimate if the economic analysis is too close to call. This narrative is particularly important is the economic analysis is unable to capture the potential costs associated with future regulatory compliance and waste management requirements.

5.2 Conducting a Pollution Prevention Opportunity Assessment

The pollution prevention opportunity assessment is one of the most important activities that a facility will perform in the planning and implementation of a facility pollution prevention program. The opportunity assessment is a tool used to define the specific characteristics of a single operation that create environmental impacts (e.g., wastes, releases of toxic chemicals to the environment, power/water usage, habitat destruction). Specifically, the pollution prevention opportunity assessment is a systematic evaluation of processes and operations to:

- Characterize all aspects of the process or operation including process flow, waste generation patterns, material and power consumption, costs, manpower, reliance on toxic chemicals.
- Define the impacts that the process and related wastes have on the air, water and land.
- Associate impacts and wastes to specific unit operations.
- Assign related costs and liabilities with specific wastes and management practices.

This detailed process information is them used to identify, refine and plan the implementation of pollution prevention activities that will reduce the environmental impacts associated with the process.

Pollution prevention opportunity assessments will be performed after the baselining activity. An opportunity assessment can be performed anytime after

Common Pollution Prevention Opportunities

When conducting an opportunity assessment, it is important to consider all types of activities. While it may be easier to focus on source reduction technologies, the pollution prevention team may end up ignoring inexpensive and easy fixes that can result in significant reductions. Changes in policy and modifications to outdated procedures often reduce waste generation as well as equipment purchase or process changes. Furthermore, training and awareness may also yield significant reductions. Training an equipment operator to properly operate a machine or increasing worker awareness about a particular procedure may eliminate an environmental or cost concern. All of the following types of activities may provide the means to reduce an environmental impact:

- Policy changes
- Procedural changes
- Equipment modifications
- Material substitution
- Training
- Efficiency improvements
- Waste stream segregation
- Housekeeping practices
- Inventory control
- Reuse of materials

A pollution prevention opportunity assessment should consider any of these

the baseline is developed to augment baseline data. Hence, opportunity assessments can be performed as part of the planning process or any time after the planning process. In general, detailed, process-specific opportunity assessments are typically performed after completion of the facility pollution prevention program plan so that environmental staff can develop priorities in conducting opportunity assessments for all candidate operations. That is, complete the facility-plan before diving into the detailed pollution prevention opportunity assessments.

The steps involved in conducting an opportunity assessment are:

- Select operations of interest based on facility goals and objectives and existing data.
- Conduct a preliminary review of the operation using existing data to prepare for the site visit.
- Conduct a site visit of the operation to identify pollution prevention opportunities, and identify implementation issues.
- Define pollution prevention options.
- Perform a feasibility analysis.

The most common problem arises from staff who don't understand why you're asking all of these questions. You need their help, so solicit their participation by:

- Explaining what you are doing and why
- Asking for their input
- Building consensus
- Being considerate of their other duties

Keys to Success in Conducting Opportunity Assessments

* Solicit the assistance and input of staff who operate the process. They are the experts.
* Build consensus among these staff on the best pollution prevention options for their processes.
* Explain why this process is important to all staff involved.
* Don't rule out any options until the team has had time to actually consider its merits and potentials.
* Don't rush. If the team has to go back for more information, do so.
* Use information sources, data systems and technical assistance services to generate ideas.

- Giving examples of how pollution prevention will make their job easier.

Remember, you can't do this alone. The staff who generate the waste will ultimately have to reduce it. They must be involved from the very beginning.

5.3 Pollution Prevention Program Plan Development

5.3.1 Introduction

A pollution prevention program plan is a tool for ensuring that pollution prevention is integrated into facility operations in a logical, cost-effective, and timely manner. Facility managers rely on program plans to provide a stepwise process for the identification and implementation of source reduction opportunities. The pollution prevention program plan serves as a map describing pollution prevention program goals, status, activities, and results. As such, the plan encapsulates a facility's environmental future with respect to all environmental impacts and governing compliance programs.

There are many different ways to prepare a pollution prevention program. The exact approach adopted by a specific facility will depend upon the type of operations (e.g., manufacturing, service sector), the organizational structure, and management style. This discussion presents an overview of the basic steps involved in designing a program plan.

5.3.2 Developing a Pollution Prevention Program Plan

Establishing Goals and Objectives

A facility is most likely to develop a successful program plan if it clearly establishes its pollution prevention goals and objectives at the project's outset. In most cases, facilities' pollution prevention goals are closely linked to their overall environmental goals such as remaining in compliance with specific regulations. Over time, the pollution prevention goals may become the backbone of the environmental program providing a solid framework for reducing environmental problems to a minimum, and complying with present and future regulations. Examples of basic pollution prevention goals are:

> Environmental Issues Potentially Considered under the Pollution Prevention Program Plan
>
> Various environmental issues may be addressed under your pollution prevention program. A comprehensive, multi-media pollution prevention program plan might include:
>
> - Hazardous Materials Use
> - Hazardous Waste Generation
> - Solid Waste Generation
> - Air Emissions
> - Discharges to Municipal Sewers
> - Discharges to Storm Sewers
> - Stormwater Runoff
> - Raw Material Storage and Spills
> - Land Use Planning and Management
> - Energy and Water Consumption
> - Mobile Air Emissions
> - Affirmative Procurement
> - Toxic Material Use Reduction
> - Habitat and Wildlife Preservation

- Reductions in release and use of toxic and extremely hazardous chemicals
- Reductions in the unnecessary purchase of toxic and hazardous chemicals
- Affirmative procurement practices to ensure the purchase of recycled content materials
- Increases in the volumes of materials captured for recycle
- Reductions in the generation of solid wastes
- Reductions in the consumption of materials, water and power
- Minimization of direct, adverse environmental impacts through land use activities and direct release of chemicals to the environment.

Obtain Management Commitment

The first step in establishing a pollution prevention program is to obtain a commitment from upper management. When management is committed to pollution prevention, the development (and ultimate implementation) of the program plan should proceed more smoothly. As with any new project, obtaining management support for pollution prevention involves providing managers with the information they need to make decisions. Managers should understand the goals of pollution prevention, the reasons for developing a pollution prevention program and the elements of a pollution prevention program. Most importantly, the facility managers should understand all of the potential benefits that they might reap in developing and implementing a pollution prevention program.

Once upper management agrees to developing a pollution prevention program plan, the facility director should sign a formal policy statement that expresses approval for the pollution prevention program. In addition to the policy statement, the upper management must provide the authority for the environmental staff to develop and implement a pollution prevention program. They should also pledge funds to finance the program.

Team Building

A pollution prevention program cannot succeed without the support of all facility staff. As such, the pollution prevention program should be developed by facility staff who work in a team with the environmental personnel who are responsible for the pollution prevention program plan. To ensure staff acceptance of any changes that will result from implementing the pollution prevention plan, the facility should involve as many people as possible during the planning process. Plan development will require input from many staff who understand and operate different processes or missions at the facility. The team may also enlist the support of staff who support the entire facility like maintenance engineers, supply staff, utilities staff and others. These staff will be invaluable in defining facility-wide characteristics and pollution prevention opportunities. Building support for the program can be achieved by:

- Enlisting middle management support

- Establishing an oversight group
- Publicizing the program
- Creating employee incentives.

Developing a Baseline

After enlisting support, the first major activity is the development of an environmental baseline. Baseline development involves building a comprehensive picture of the materials usage patterns and environmental impacts associated with the facility. To develop a complete baseline, the pollution prevention team will integrate environmental data into a unified, multi-media description of the facility's environmental impacts. The baseline will define materials usage patterns and the environmental problems that arise from these usage patterns. To obtain this information, the team will search through records and talk with people involved with all of the operations. The team may also use a survey sent to each activity at the facility to collect the needed data. Examples of the kind of questions to ask are:

- What volumes of chemicals are released?
- How does the purchasing and supply department order, receive, and distribute materials for the facility?
- What products or services are being conducted at the facility that consume materials?
- What wastes and pollutants are being generated by the use of the materials?
- What processes are generating these wastes and pollutants?
- What are the volumes and characteristics of the wastes being generated?
- How are wastes managed following their generation?
- What problems are associated with the management or mismanagement of these wastes, and how they are disposed of?
- What are the annual disposal costs?
- What impacts are these activities having on the natural resources and land, not only on the facility's property, but beyond its borders as well?

Baseline development can be a time-consuming process especially if the quality of existing environmental facility data is poor. The pollution prevention team should begin by developing the baseline for areas that help satisfy the facility's primary goals and objectives. Over time, the team can complete the baseline for other areas. As part of this process the team will identify pollution prevention opportunities. It should document these opportunities and incorporate them into the facility pollution prevention plan.

5.3.3 Identify Pollution Prevention Activities

Using the baseline data, the pollution prevention team can identify the pollution prevention activities of greatest concern. For example, the baseline may indicate that water usage is a critical issue for a facility. If water is a critical issue, what activities can be initiated to reduce usage, waste and overall cost? For every issue documented under the baseline, the team should identify activities that will promote pollution prevention. In general, these activities will include the following.

- **Additional Analysis**—The baseline may illustrate that a process or environmental impact is not fully understood. That is, more complete information or data is needed. To fully characterize the problem, the environmental staff will have to conduct analyses, analytical measurements or studies. Upon completion of these analyses, the staff will assess pollution prevention opportunities.
- **Immediate Implementation**—The baseline may illustrate applications of existing pollution prevention strategies, techniques or technologies that can be implemented immediately to reduce environmental impacts. In such cases, the facility may seek to implement pollution prevention options immediately.
- **Pollution Prevention Opportunity Assessments**–the baseline may also illustrate that processes may be amenable to pollution prevention options. To define the best option, the staff will want to conduct a pollution prevention opportunity assessment.

To set priorities among all of the types of activities, the team should focus on those processes which are responsible for the environmental issues or impacts of greatest concern and the most appropriate type of action. Setting priorities requires weighing different objectives, such as toxic use reduction, cost reduction, or water use minimization. Each facility will have its own objectives depending on its overall pollution prevention goals and site-specific conditions.

The pollution prevention program plan will a list of all of the pollution prevention activities identified in this step. The facility pollution prevention plan will act as a road map that ties all of the additional analyses, immediate implementation and opportunity assessment activities together. As activities are completed or new ones identified through pollution prevention opportunity assessments, the list of prevention activities will change.

5.3.4 Develop Criteria and Rank Pollution Prevention Activities

The next step is to develop priorities and rank the pollution prevention activities. That is, develop a list of action items to integrate pollution prevention into the facility's activities. The order in which the facility chooses to initiate pollution prevention activities and projects will depend upon facility-specific considerations and environmental goals. These considerations will be used to rank all of the pollution prevention activities identified previously. The following are commonly used in ranking such activities:

- **Mission Impact**—The project's potential impact on the facility's mission (e.g, will project implementation jeopardize the mission by making it more difficult for a shop to carry out its work).
- **Environmental benefits**—The project's environmental benefits (e.g., air emission reduction from the plating line, hazardous waste minimization of metal bearing sludges).
- **Environmental compliance**—The project's impact on the facility's overall environmental compliance status.
- **Ease of implementation**—A measure of the ease of implementing the project. Complex changes that require additional effort by staff may not be as easily accepted as simpler changes.
- **Cost savings**—The potential cost savings associated with project implementation. Pollution prevention techniques that result in improved efficiency and cost savings are usually accepted more readily than options that result in increased costs.

After the team has identified ranking criteria, it should rank all pollution prevention activities identified on a numerical scale by assigning a value that reflects how the activity matches each criterion. The activity which ranks highest in all criteria (i.e., the opportunity with the highest total score) should be considered first for implementation. Often, one criterion is considered to be more important than the others. In this case, a weighting factor should be applied to the criteria that are valued more highly.

An example of a hypothetical decision matrix for a metal finishing shop is presented in **Exhibit 5-3.**

The product of this activity is a list of pollution prevention action items that the team plans to pursue to implement the pollution prevention program. The list may include a combination of additional analyses, immediate implementation and opportunity assessment activities. This list, once approved by management, will become the implementation plan for the pollution prevention program.

5.3.5 Conduct Management Review

Once the pollution prevention team has developed a ranked list of pollution prevention activities, it should secure upper management and senior staff support. This is an important opportunity for upper management to reaffirm its support for the pollution prevention program. To do this, the team should convene a management review committee to include representatives from all of the organizations that will be affected by the pollution prevention program. Upper management should understand the relationship between the pollution prevention program activities and their impact on the facility mission and existing environmental programs. The end product of all the pollution prevention projects should be a coherent, integrated pollution prevention program that supplements other facility programs (e.g., health and safety, environmental compliance, training and development).

Exhibit 5-3. Ranked Options for a Hypothetical Metal Plating Shop

Option	Cost Savings	Environmental Benefit	Worker Health	Effect on Compliance	Totals
Use a less toxic degreaser	5	5	4	4	18
Reduce volume of hazardous materials stored on-site	4	4	3	4	18
Install counter-current rinsing	5	4	3	4	14
Provide pollution prevention training for operators	4	4	4	5	16

Appendix A – International Policy Approaches to Encourage and Implement Pollution Prevention/Cleaner Production

A.1 U.S. Policy Approaches to Pollution Prevention

The U.S. Environmental Protection Agency (USEPA) defines pollution prevention as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste streams or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal and reduces hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants. It includes practices that result in increased efficiency in the use of raw materials, energy, water, or other resources, or protection of natural resources by conservation. [19]

Similarly, cleaner production is defined as including those practices that reduce the amounts of energy and raw materials based on natural resources needed to produce, market, and use products. At the same time, production, marketing, and disposal of these products should also be such that releases of potentially harmful contaminants to environmental media are kept as low as practicable. [8]

It is apparent that the same basic tenets apply to what most Organisation for Economic Cooperation and Development (OECD) governments refer to as either pollution prevention or cleaner production. In the past decade, many of these countries have been applying increased scrutiny to environmental issues in general and to pollution prevention/cleaner production techniques specifically.

The following sections examine the pollution prevention/cleaner production policy and programmatic options employed in the United States and other OECD member countries as they relate to the metal finishing industry. Section 4.2 discusses the U.S. policy options as enacted through various federal statutes and Presidential Executive Orders and provides an evaluation of these policies as they relate to the industry. Section 4.3 provides an overview of State and local programs in the United States. Section 4.4 characterizes international pollution prevention/cleaner production programs, including both an overview of individual country programs and regional policies where available. Appendix A provides a list of pollution prevention contacts who have further information on U.S. and OECD policy approaches.[1]

Exhibit A-1 provides a summary and overview of U.S. policies and options. For a detailed description of these policy approaches, see Appendix C.

A.2 Federal Pollution Prevention Executive Orders

In addition to the federal statutory law in the United States, numerous recent Executive Orders also require or promote pollution prevention. Generally, these Executive Orders are binding on the federal government and affiliated entities. For the most part, these Executive Orders are broad in scope and not industry-specific. Therefore, these Executive Orders are simply summarized in **Exhibit A-2**. These Executive Orders will affect federal facilities where Metal Finishing is conducted, as well as other facilities. However, Executive Order 12843 (4/21/93), which concerns the procurement requirements and policies for federal agencies for ozone-depleting substances, will have a greater impact on facilities that conduct metal finishing than on many others.

A.2.1 Executive Order 12843

Executive Order 12843, Procurement Requirements and Policies for Federal Agencies for Ozone-depleting Substances (April 21, 1993), recognizes the importance of addressing the current depletion of the ozone layer caused by the worldwide use of various ozone depleting substances (ODS). This issue is addressed in the U.S. Clean Air Act and also in the Montreal Protocol to which the United States is a signatory.

The Montreal Protocol calls for a phaseout of the production and consumption of ODS and, as a signatory, the United States is using Executive Order 12843 as another tool in achieving this goal. Agencies are directed to accomplish several important objectives. Procurement regulations and policies must be revised to conform with the requirements of Title VI of the Clean Air Act that address stratospheric ozone protection. Agencies are also directed to maximize their use of alternatives to ODS by evaluating current and future uses of ODS to identify opportunities for recycling. Procurement specifications and practices must be modified, whenever economically practicable, to substitute non-ODS for those ODS that are currently purchased and used. In addition, agencies were directed to submit a report summarizing efforts to implement the specific provisions of this order to

Exhibit A-1. Summary of U.S. Policies and Programs

Policy Approach/ Mechanism	Application to Metal Finishing	Policy Implications
	Direct Regulation	
Pollution Prevention Act	• Sets out USEPA activities to promote pollution prevention. • Establishes pollution prevention grant program. • Establishes clearinghouse to promote information transfer. • Requires annual source reduction and recycling report. • Requires biennial Report to Congress.	• Institutionalizes pollution prevention in all programs. • Creates incentives for States to pursue pollution prevention. • Initiates activity addressing federal pollution prevention issues. • Starts to measure progress and identify key issues. • Promotes broad-based pollution prevention.
Resource Conservation and Recovery Act	• Establishes source reduction as key component of National policy. • Requires all hazardous waste generators to certify that they have a program in place to reduce the volume or quantity and toxicity of hazardous waste that they manage. • Regulates several metal finishing wastes as hazardous waste.	• Fosters source reduction and recycling among all hazardous waste generators. • Rigorous regulatory scheme applicable to metal finishing wastes that are hazardous wastes create strong financial and liability incentives to pursue source reduction.
Clean Water Act	• Authorizes technology-based, industry-specific national limits on amount of regulated pollutants a facility can discharge to water.	• Raises cost of treatment and disposal and creates financial incentives for source reduction. • Achieves waste reduction through in-plant controls.
Clean Air Act	• Regulates 189 air toxics and requires pollution prevention measures, including control equipment, process changes, substitution of materials, changes to work practices, and operator training and certification. • Requires the phase-out of production and sale of chlorofluorocarbons (CFCs) that contribute to destruction of ozone layer. • New sources located in non-attainment areas must use most stringent controls and emissions offsets.	• Increases cost of generating air emissions produced by metal finishers, increasing incentives for waste reduction. • Restrictions on CFCs limit some chemicals used by metal finishers. • Offsets may be achieved through pollution prevention.
Emergency Planning and Community Right-to-Know	• Requires select industries to report environmental releases of specified toxic chemicals (Toxic Release Inventory [TRI]). • Applies to metal fabricating category and other industries that conduct metal finishing.	• Reporting requirements create strong incentives to reduce waste generation and toxics releases. • Release data increased industry and public scrutiny of waste generation and manufacturing operations. • Used to measure waste reduction.

Exhibit A-1. Summary of U.S. Policies and Programs (Continued)

Policy Approach/ Mechanism	Application to Metal Finishing	Policy Implications
Executive Orders		
Executive Order 12843	• Requires federal agencies to implement Montreal Protocol.	• Requires the phase-out of such chemicals as 1,1,1-trichloro-ethane and replacement with less harmful substances.
Enforcement		
Supplemental Environmental Projects (SEPs)	• Allows USEPA enforcement actions to mitigate portions of fines or penalties in exchange for respondent undertaking pollution prevention projects.	• Provides a major incentive for industries subject to enforcement actions to undertake pollution prevention projects.
Voluntary Programs		
USEPA 33/50	• Promotes ambitious targeted reduction of 17 key toxics by participants, including members of metal fabricating industry and others conducting metal finishing.	• Promotes activity and commitment at level closest to the manufacturing process.
Waste Reduction Evaluations at Federal Sites	• DoD/USEPA initiative to evaluate pollution prevention at federal facilities and to promote technology transfer using reports, project summaries, conferences, and workshops.	• Creates waste reduction culture within federal facilities. • Provides access to key pollution prevention information.
Design for the Environment	• Promotes voluntary consideration of waste in and risk in to process and product design stage,	• Creates interest in waste and risk reduction. USEPA initiated metal finishing projects to develop energy, environment, and manufacturing assessment methodology.
Source Reduction Review Project	• Integrates source reduction considerations across USEPA program offices through specific rulemakings.	• Increases use of media-specific regulatory programs to promote source reduction where possible.
Pollution Prevention Grants	• Provides of EPA grants to States and funds joint federal agency projects.	• Promotes pollution prevention activity at State and federal level, including waste reduction in metal finishing industries.
Technology/Policy Transfer	• Promotes development and dissemination of technical and non-technical pollution prevention information.	• Promotes availability and benefits of waste reduction. Provides network of resources to used for specific projects.

the Office of Management and Budget by October 23, 1993. A more detailed discussion of the Montreal Protocol is presented in Section 4.4.2.

A.2.2 Implication and Evaluation of Policy

Executive Order 12843 has impacted and will continue to affect the metals plating industry. The most prominent effect has been the requirement to phase out solvents used for metal cleaning, such as 1,1,1-trichloroethane. These requirements have forced U.S. metal plating operations to identify replacements, which include aqueous and semi-aqueous degreasers.

A.3 State and Local Programs

A.3.1 Introduction

Over the past 7 years, the number of State and local pollution prevention programs has grown tremendously. In USEPA's 1986 report to Congress, the agency identified 19 states as having some form of program for providing technical assistance or information to companies attempting to minimize hazardous waste. Now, in 1995, almost every state has some form of limited program or support for pollution prevention.

Exhibit A-2. Summary of Executive Orders Addressing Pollution Prevention

Executive Order	Summary of Major Provisions
EO 12759 (4-17-91) *Federal energy management*	Encourages Federal agency energy management, including use of alternative, less-polluting fuel, reduced petroleum product use, and employee outreach.
EO 12780 (10-31-91) *Federal agency recycling and the Council on Federal Recycling and Procurement Policy*	Directs federal agencies to promote cost-effective waste reduction and recycling activities. Requires all federal agencies to develop an affirmative procurement program to purchase products with recycled content. Creates the Council on Federal Recycling and Procurement Policy, which encourages Federal agencies to purchase products that reduce waste generation, assists in the development of waste reduction and recycling programs, and collects and disseminates information on waste reduction methodologies, costs and savings, and recycled content products prices.
EO 12843 (4-21-93) *Procurement requirements and policies for federal agencies for ozone-depleting substances*	Directs all federal agencies to maximize their use of alternatives to ozone-depleting substances, evaluate present and future needs for ozone-depleting substances, develop recycling initiatives to reduce and prevent ozone-layer degradation, and modify procurement specifications and practices to require non-ozone depleting substances for ozone-depleting substances.
EO 12856 (8-3-93) *Federal compliance with right-to-know laws and pollution prevention requirements*	Requires toxic chemical and hazardous substance reporting. Procurement process revisions to reflect source reduction principles and on-site innovative pollution prevention technologies testing for market development.
EO 12902 (3-9-94) *Energy efficiency and water conservation at federal facilities*	Requires federal agencies to develop and implement programs to reduce energy consumption and increase energy efficiency at their facilities and buildings using prioritization studies, facility audits, and energy efficient, water conserving, and renewable energy technologies, including solar power and petroleum product alternatives.

A wide variety of approaches to pollution prevention has been adopted by State and local programs reflecting differences in industrial profiles, environmental releases, business cycles, and the political climate. Pollution prevention has gained support relatively quickly because it is seen as a unique philosophy enabling States to pursue both economic development and environmental quality objectives—objectives that are more commonly seen as irreconcilable. Public pressure combined with the activities of both national and locally based environmental groups have helped move pollution prevention legislation through State legislatures.

As a gross generalization, State/local programs can be classified into *regulatory* programs and *non-regulatory* programs. Under a regulatory approach, State legislation gives environmental agencies the authority to require industry to comply with requirements such as mandatory facility planning. In addition, environmental agencies may integrate pollution prevention into traditional regulatory activities, such as inspections, permit writing, and enforcement actions. Under a non-regulatory approach, States establish a voluntary program for encouraging industry to reduce environmental releases to all media. Many non-regulatory States still maintain a pollution prevention staff in their regulatory agencies to run a technical assistance program and/or to incorporate pollution prevention concepts into existing media-specific programs.

A.3.2 Overview of State and Local Approaches to Pollution Prevention

As of 1994, 24 States have legislation or regulation promoting or mandating pollution prevention facility planning, and more are considering (or have considered) such legislation. Only 16 of the 24 States, however, require companies to develop plans. In

The Massachusetts Blackstone project is the best known pilot multi-media inspection. The project focused on electroplating and metal-finishing facilities in the area served by the Upper Blackstone Publicly Owned Treatment Works. A team would inspect the entire facility for violations affecting all media. If violations were found, Department of Environmental Protection (DEP) inspectors would take the appropriate level of enforcement and, within the context of the enforcement action, recommend that the facility seek source reduction technical assistance from the non-regulatory Office of Technical Assistance (OTA). OTA developed an active technical assistance program for companies in coordination with DEP's inspections, including regular meetings with an Advisory Board of local electroplaters and metal finishers, on-site assessments, and workshops. Interestingly, 97 percent of the firms receiving notices of noncompliance made use of the OTA program.

addition, most States do not have enforcement provisions to assure implementation of the plans. Although there are significant differences in planning requirements, the plans share certain elements. States have begun taking action in the following regulatory areas: facility planning, multi-media inspections, enforcement, and permit writing. The activities in each of these areas are summarized in **Exhibit A-3.** Many States have both regulatory and non-regulatory elements in their pollution prevention programs with the latter serving to assist the regulated community through technical assistance and outreach (e.g., New Jersey, Minnesota, Tennessee, Indiana). The basic philosophy underlying the non-regulatory approach is that government should not dictate to private companies how to run their businesses through environmental requirements. The philosophy assumes that left on their own, most companies will reduce their environmental releases because of rising compliance costs and other incentives. The primary goal of the technical assistance programs is to overcome the barriers to pollution prevention. In terms of their scope, the non-regulatory programs provide assistance in a wide range of areas such as compliance, hazardous waste minimization, solid waste recycling, wastewater, and air emissions reductions.

State and local pollution prevention programs are still in their infancy, and most analysts agree that it is too early to draw conclusions as to whether a regulatory or a voluntary approach is more effective. Since each OECD member country has its own regulatory context and its own government-industry dynamics, evaluating U.S. successes and failures with these two approaches may not be very informative. Instead, the remainder of this section describes some of the activities and approaches of State and local governments.

Appendix C summarizes the common elements of State pollution prevention programs. Several states, including Minnesota, Wisconsin, North Carolina, and Michigan, have held workshops and prepared publications to specifically assist metal finishers.

The Water Services Department of Phoenix, Arizona, established a pollution prevention program to develop best management practices for industrial and commercial facilities that discharge one or more pollutants of concern and to implement a public outreach program to reduce the discharge of toxic substances to the wastewater treatment plants.

The pollution prevention program has created two innovative games designed to improve awareness of pollution prevention. The game created for industrial facilities, "Pollution Prevention Pays," asks participants a series of questions in different industrial categories, including metal finishing, printed circuit boards, and metal fabrication. Participants score points for correct responses. The game for the general public, "Be a Pollution Solution," includes questions in various categories, including environmental awareness, product substitution, and household hazardous waste.

City and county level governments increasingly are active in pollution prevention. As more and more landfills reach capacity, governments view pollution prevention as an important method for extending the operating lives of their local landfills. Examples of local initiatives are highlighted in this section. In addition, many counties are working with State regulatory agencies and local environmental groups to make pollution prevention part of the wastewater pretreatment program. Wastewater treatment plants identify the source of toxics in the system and provide technical advice and other assistance to help the discharger implement toxic use reduction and other pollution prevention measures as a way to meet pretreatment requirements. A few of the states with local governments active in this area are Massachusetts, Arizona, New York, New Mexico, and California.

The City of New York's Department of Sanitation is in the process of launching a major pollution prevention initiative, which involves conducting more than 25 assessments in eight industrial categories, public education, and implementation followup. Also in New York State, the Erie County Office of Pollution Prevention's technical assistance program has

Exhibit A-3. State Pollution Prevention Activities

Area	Activity/Elements
Facility Planning[1]	• A policy statement of management support for pollution prevention, and a schedule for meeting the goals. • A statement of reduction goals, the reasoning behind them, and a schedule for meeting these goals. • A description of efforts initiated in the past that qualify as pollution prevention and an assessment of those efforts' successes and failures. • A detailed, numeric description of current processes in which toxic chemicals are used and hazardous wastes generated. • Identification of pollution prevention options in specified areas, including (at a minimum) changes in a product or its formulation, substitution of raw materials in existing processes and products, equipment modification or modernization, and changes in operating and maintenance procedures. • Detailed financial and technical analyses of practical application of identified options in light of current operating conditions. • Detailed criteria or rationale for choosing or discarding identified options for implementation. • A detailed schedule for implementing selected options, and procedures for measuring and monitoring their progress in achieving reductions. • A description of opportunities for employee involvement and training. • Certification by responsible corporate officials or facility managers. • State facility planning legislation/regulations differ as to the regulated community, the media/waste/materials covered by the requirement, targets for reductions, State required approval of facility plans, public access, enforceability, and measuring progress against a baseline.
Multi-Media Inspections	• Several States (MA, KY, MN, WI, NY, VT) are using (or planning on using) compliance inspections as a means of promoting pollution prevention. • By training inspectors to identify pollution prevention opportunities during the inspection, State regulatory agencies hope to create leverage for pollution prevention through stringent evaluations of compliance, combined with directing facility operators toward technical assistance programs.

[1] *Building State and Local Pollution Prevention Programs*. USEPA. EPA/130-R-93-001. December 1992, pp. 69-70.

Exhibit A-3. State Pollution Prevention Activities (Continued)

Area	Activity/Elements
Enforcement[2]	• Reducing penalties where toxics use reduction or source reduction is chosen as the approach to compliance • Requiring facilities with compliance violations to undertake a pollution prevention audit, or institute a pollution prevention planning process. • Requiring specific pollution prevention measures to come into compliance. • Allowing additional time for facilities to explore pollution prevention compliance alternatives.
Permit Writing	• Request the facility to adopt "Best Management Practices" under the Clean Air Act or the Clean Water Act. • Permits set numerical standards for discharges and emissions, and in same instances may also specify the kinds of equipment and operating procedures that will be used. • Little precedent for requiring facilities to comply with pollution prevention reductions using certain kinds of technologies. • New Jersey established a pilot project for 10 to 15 industrial facilities in facility-wide permitting.
Technical Assistance Programs	• Assist private companies with pollution prevention • Assist private companies with regulatory interpretation • Provide training for State regulatory staff, POTW operators • Develop curriculum for students • Promote recycling • Facilitate information exchange • Funded by USEPA competitive grant awards, annual USEPA hazardous waste program grant to States, fees and waste disposal taxes (e.g., Community Right to Know (NJ), hazardous waste management fees (VA)), general environmental budget established under legislation. • Utilize university-based programs with small staffs of student interns and faculty (e.g., the University of Tennessee, the Solid and Hazardous Waste Education Center of the University of Wisconsin-Extension). • Prepare State environmental staff for pollution prevention work (e.g., the Toxics Use Reduction Institute, University of Massachusetts at Lowell). • Incorporate pollution prevention into the activities of State agricultural extension offices (e.g., WI, IN, AL). • Promote pollution prevention through small business economic assistance programs and cooperative efforts with local chapters of industry and trade associations. • Staff the technical assistance programs with retired engineers.

[2]State Pollution Prevention Programs: Summary and Current Trends. Draft. USEPA. March 1994, p. 12.

Lincoln-Lancaster County Health Department (LLCHD) in Nebraska developed a program to reduce toxicity through pollution prevention by increasing public understanding of chemical toxicity in relation to decisions made on product purchase, use, handling, storage, and disposal. By ordinance, all businesses in the county need to fill out a waste inventory; those who wish to dispose of special waste need a permit. This process educates businesses in appropriate disposal methods and gives the county an opportunity to identify pollution prevention options for the business owner. The LLCHD offers all businesses on-site assistance in developing waste reduction strategies. LLCHD covers pollution prevention in air,

worked with metal finishers. The office has assisted public development programs in incorporating pollution prevention into their funding approval criteria. It also works with local wastewater treatment plants to incorporate pollution prevention into routine inspections.

California has the widest variety of local government units active in pollution prevention. Several of the large coastal metropolitan areas have their own programs (e.g., Irvine, Berkeley, San Diego, San Francisco, Los Angeles, California). The Sanitation District of Los Angeles County has its own program to work with businesses that discharge to the wastewater treatment plant and dispose of waste at the landfill facility.

A.3.3 Regulatory vs. Voluntary Approaches

The focus of State/local pollution prevention programs has slowly shifted away from the voluntary approach toward the regulatory approach, particularly in the case of States with large releases of toxic substances to the environment. States with relatively limited industrial bases have generally chosen to remain with the voluntary approach. In crafting their programs, State policy makers have wrestled with a number of fundamental issues that other countries may also encounter:

- Economic Growth and Environmental Quality Goals. Up-front investments in process modifications and new technologies can lead to long-term savings in raw material costs, energy and water cost reductions and labor, as well as waste management and disposal. The challenge is to ensure that as many companies as possible not only identify cost savings opportunities but *implement* pollution prevention measures. States could target industries under economic stress because management may be more interested in making money-saving changes when other options are limited than when their profit levels are comfortably acceptable. Alternatively, States could target industries on the volume of waste generated, air emissions, or wastewater discharges. Legislation in some States is aimed specifically at reducing hazardous waste rather than releases of toxics to all media while other States target toxics reductions. The decision as to whether a regulatory or a voluntary approach is more appropriate in a particular State depends on several factors, including environmental protection goals, funding, prior voluntary reductions, the relationship between stakeholders, and macroeconomic and social policy considerations.

- Leveling the Playing Field. Although State and federal pollution prevention policies have been established only recently, some companies have been practicing pollution prevention for many years. States that considered requiring all industries to reduce their wastes by a certain percentage by a specified year met fierce resistance from companies that had already made costly investments in pollution prevention and argued that they should receive credit for earlier reductions. In addition, smaller companies, such as many metal finishers, typically lack the potential cost savings, public image incentives, and capital to invest in new equipment or to research process changes. (A summary of the barriers and incentives to pollution prevention from the perspective of private industry is presented in **Exhibit A-4**.)

- Relationship Between the Regulated Community and the Regulators. Most company managers are not willing to allow a pollution prevention specialist from a regulatory agency to conduct an on-site assessment because they are concerned that the representative may identify compliance violations during the assessment that would be reported. This is particularly true in a heavily regulated industry, such as metal plating. States with active, high-profile enforcement programs have found that the technical assistance and outreach elements of the pollution prevention program are better handled by a non-regulatory agency, such as a university.

- Organizational Structure. Environmental agencies' responsibilities are partitioned according to environmental media. Agencies must break through the institutional barriers that have traditionally separated individual program areas, reconsidering the way in which information about individual facilities is collected and managed by

Exhibit A-4. Barriers and Incentives to Pollution Prevention

Barriers to Pollution Prevention	Incentives for Pollution Prevention
Regulatory – Restrictive regulations – Uncertainty – Overlap of requirements	Regulatory – Stringent regulations – Mandated pollution prevention
Economic – Lack of capital – Current cost accounting practices – Financial risk	Financial – Reduced compliance costs – Reduced raw material and utility costs – Federal and state loans and grants
Technological – Unproven technologies – Lack of technical expertise – Industry diversity	Technological – Off the shelf technologies
Corporate Management – Resistance to change – Lack of senior management support – Organizational difficulties – Short-term planning frame	Corporate Management – Support
Cultural – Perception of risk – Poor dialogue	Cultural – Corporate image
Availability of Information – Lack of methods to measure progress – Lack of trust in available information	Availability of Information – Information networks
Enforcement – Inconsistent enforcement	Enforcement – Flexible enforcement strategies

each department, the way in which inspectors and other environmental staff are trained, separate annual program budgets and staff resources, and political territories.

A.3.4 Conclusion

One of the greatest challenges facing State and local programs is the need to document program successes in some cases to ensure ongoing funding. The National Roundtable of State Pollution Prevention Programs, a nationwide consortium of regulatory and non-regulatory representatives, has grappled with this issue. The most commonly reported methods for quantifying program success are summarized in **Exhibit A-5.** While quantifying progress in waste reduction will always be challenging, the Toxic Release Inventory (TRI) reports should help State and local governments collect data on progress made by at least the larger companies. Attributing companies' pollution prevention achievements solely to State program activities, however, may be taking too much credit because, as this section discussed, many factors are involved in a company's decision to invest in pollution prevention.

Looking to the future, State and local governments should expand their sharing of experiences, resources, and information through

Exhibit A-5. Commonly Reported Methods for Quantifying Program Success

Regulatory Programs	Non-Regulatory Programs
Number of: • Multi-media inspections/enforcement actions • Permits issued • Grants or loans issued • Reduction in waste generated as reported on State annual reports and facility plans	Number of: • Client contacts (e.g., hotline phone calls, on-site visits) • Workshops given and participants • Publications distributed • Waste exchange transactions

programs such as the National Roundtable. Improved cooperation will enable programs to use their limited resources efficiently. Specific areas may include experiences with facility planning implementation, database development of proven technologies, and publications and training. Similarly, federal agencies have much to share with State and local government, as well as with the private sector. Agencies such as the Department of Defense and the Department of Energy are investing in pollution prevention research and training development. Some of their work is relevant to the private sector.

A.4 International Programs

A.4.1 Waste Exchanges

> Waste Exchange Characteristics
>
> - Operates as clearinghouse with printed and/or electronic list of materials available.
> - Serves as intermediary between lister and interested entity or provides direct access to lister, but does not solicit matches.
> - Does not take possession of material or warrant condition/usability of material.
> - Funded by federal, State, and local governments, private donations, or listing/subscription fees.
> - Covers limited geographical area but may participate electronically in regional or national databases.

Waste exchanges provide a mechanism for facilitating the transfer of waste materials from generators to entities interested in recycling or reusing these materials. Generators reduce their disposal costs, reduce disposal quantities, and possibly receive revenues. Entities accepting waste materials obtain inexpensive raw materials, thus lowering operating and production costs. Exchanges successfully facilitate the transfer of tons of industrial waste annually worldwide. Evaluating and measuring their success is extremely difficult due to a lack of data.

Waste exchanges may represent a particularly powerful tool for the metal plating industry and metal plating wastes. As the data in **Exhibit A-6** illustrate, many wastes typical of metal plating operations (e.g., acids, alkalis, metal and metal sludges, solvents) are routinely listed by North American exchanges. Wastes such as spent acids, caustics, and solvents may be readily used for less exacting applications. Wastes containing valuable metals may be worthy of recovery or used as feeds to other processes. Similarly, metal platers may be able to use these waste streams as feedstocks if the purity of the materials is adequate.

A.4.2 Montreal Protocol

The Montreal Protocol[2] is one of the most influential international environmental directives affecting the metal finishing industry. The goal of the Montreal Protocol is to protect the ozone layer from man-made ODS, some of which traditionally have been utilized in the metal finishing industry (e.g., 1,1,1-trichloroethane), by phasing out their use.

USEPA has pursued numerous activities that will aid in the phaseout, including the identification of substitute chemicals, products, and technologies; promulgation of regulations to implement the Protocol; and publication of a list of approved alternatives to ODS.

The Heads of Delegations representing Sweden, Finland, Norway, Switzerland, Austria, Germany, and Denmark called for more stringent control measures, including a phase out on the production and consumption of CFCs, halons, and carbon tetrachloride as soon as possible, but no later than 1997; a phase out of methyl chloroform as soon as possible, but no later than the year 2000; and further limits on HCFCs. In November 1992, the Protocol was again amended to accelerate various phaseout schedules and banned other chemicals. The amendment covers CFCs, halons, carbon tetrachloride, methyl chloroform, and hydrobromofluorocarbons. Methyl chloroform faces

Exhibit A-6. Listings of Materials Wanted and Materials Available by Category from the National Material Exchange Network* - January 1 to May 19, 1993

Category	Materials Available: Number of Listings	Materials Available: Percentage of Total	Materials Wanted: Number of Listings	Materials Wanted: Percentage of Total
Acids	197	3%	50	3%
Alkali	181	2%	51	3%
Construction Material	45	1%	27	1%
Container and Pallet	366	5%	79	4%
Durable and Electronic	32	0%	45	2%
Glass	39	1%	15	1%
Laboratory Chemicals	2,350	32%	8	0%
Metal and Metal Sludge	367	5%	234	12%
Miscellaneous	677	9%	278	15%
Oil and Wax	234	3%	84	4%
Other Organic Chemicals	410	6%	82	4%
Other Inorganic Chemicals	508	7%	97	5%
Paint and Coating	96	1%	11	1%
Plastic and Rubber	826	11%	505	27%
Solvent	313	4%	67	4%
Textile and Leather	165	2%	70	4%
Wood and Paper	594	8%	196	10%
	7,400		1,899	

* These data do not include approximately 460 listings of available materials and 150 wanted listings from the Southeast Industrial Exchange and the Southern Waste Information Exchange based on recent catalog listings.

a 50-percent reduction in 1994, an 85-percent reduction starting January 1, 1995, and a 100-percent elimination by January 1, 1996.

As a result of the Montreal Protocol's ambitious phaseout schedule, the metal finishing industry's widely used cleaning solvent, methyl chloroform (1,1,1-trichloroethane), will be prohibited, leaving many metal finishers to seek safer alternatives.

A.4.3 An Overview of Individual Country Programs

The policies and programs of various individual countries are summarized in Appendix A. **Exhibit A-7** provides an overview of these policies.

A.4.4 The European Community

The European Community (EC) is a unique international organization that has the power to promulgate regulations that are binding on member nations or directives that leave each member nation free to choose the particular means of implementation.

The EC recently adopted a directive aimed at reducing and controlling pollution from industrial installations. The directive introduces a system of integrated pollution prevention and control (IPPC), which is distinguished by its cross environmental media approach. Until recently, pollution control in many European countries was based on an approach that considered emissions to air, water, and land separately. Member states are expected to incorporate IPPC into their national laws by June 30, 1995.

The IPPC requires that operators of industrial installations in specific categories with a high potential to cause pollution to obtain a permit in order to operate. The directive covers the production and processing of metals, as well as installations using more than 200 kg/h of organic solvent. Smaller scale operations are generally excluded from the scope of the directive. Permit applications must describe proposed measures to prevent or minimize emissions from the installation and provide evidence that the installation meets at least the emission limit values

Exhibit A-7. International Waste Minimization Programs

	Policy Approach	Scope	Implications
Australia	• Best available technology (BAT) regulations (permitting)	• Municipal solid waste (MSW) and industrial firms with less than 250 people—some specific waste streams	• BAT regulations allow flexibility for emerging technologies/job shops escaping regulation
	• Economic—financial assistance	• Specific industries, including electroplating	• Financial assistance to induce industry implementation of waste minimization
Canada	• "Green Plan"	• Technical assistance for reduction of all waste by 50% by year 2000	• Strictly voluntary—results hard to predict
	• User charges and taxes	• MSW and industrial	• Involvement to reduce waste
	• Mandate Federal Government waste reduction	• Federal Government—all waste	• Provides example
Denmark	• Statutory orders—packaging and recycling	• MSW	• Reduces solid waste
	• Permitting	• All industry	• Limits emissions to all media
	• Financial-taxes, duties, fees, grants, subsidiary	• All waste	• Encourages use of clean technologies
Finland	• Sustainable development statute and regulations	• Rational use of all national resources	• Mandatory reduction of industrial toxics
	• Permitting	• Large industrial firms	• Job shops escape regulation
	• Financial-surtax	• MSW, fuels, and waste oil	• No effect on metal finishing
	—Grants	• Industry	• Implement innovative clean technology
Germany	• Statutory and regulations	• MSW and industrial	• Specific media regulations require clean technologies to eliminate emissions
	• Financial-disposal	• Costs for disposal of wastes such as metal finishing	• Grant incentive for clean technology
	—Low interest loan	• Industrial	• Covers cost up to 60% of investment in cleaner technologies
Italy	• Financial-priority benefits contributions	• Industry	• Encourages use of clean technologies
	• Regulations	• Industrial waste	• General not industry-specific
	• Education/demonstration/ information	• All waste	• Encourages waste minimization-not industry specific
Norway	• Statute & permits requirements—mandatory plans	• Industry	• Encourage waste minimization generally
	• Financial-subsidiaries	• Industries (also MSW)	• Financial incentive to invest in clean technologies

Exhibit A-7. International Waste Minimization Programs (Continued)

	Policy Approach	Scope	Implications
U.K.	• Voluntary	• Industry	• Not measurable
	• Statutory regulations (IPC)	• Industrial emission standards	• Mandates clean technologies, especially metal finishing; prohibited clearing and finishing technology
	• Education/demonstration	• Disseminate case studies to industries	• Technical transfer to teach and encourage use of clean technology
	• Financial-grants	• Industrial (also MSW)	• Pays up to 50% of investment with clean technology
EC	• International directives and regulations	• Industrial in member countries	• Binding on member conditions, multimedia focus on industrial waste minimization
	• BAT permits	• Industrial	• Limit industrial emission
Nordic Council	• Regional Cooperative Voluntary-education	• Industrial networks, industrial seminars, newsletters	• Technical transfer to educate and encourage individual to voluntarily engage in cleaner technology

required to give a high level of protection to the environment.

A.4.5 The Nordic Council

The Nordic Council was formed to promote cooperation among the parliaments and governments of Denmark, Iceland, Norway, Sweden, and Finland. The Nordic Council of Ministers met in March 1992 and developed the Nordic Action Programme on Cleaner Technologies. The program is divided into the following four areas: promotion of the use of cleaner technologies through exchange of experience and results, substitution of toxic components and of products that impede recycling, employment of administrative control measures to encourage the use of clean technologies, and education on clean technologies.

To further the above goals, the Council set up an industry network to disseminate information on Nordic cleaner technologies, hosted industry-specific seminars, established a Nordic newsletter, and established closer ties with the United Nations Environment Programme's cleaner production activities. In addition, work is being carried out on standardizing the methodology of life cycle assessment.

A.4.6 NAFTA

The recent passage of the North American Free Trade Agreement (NAFTA) highlights a challenging situation concerning how to reconcile international trade and environmental policy issues. NAFTA raises issues such as how trade agreements can be achieved in the context of heavy environmental regulation and how to harmonize international environmental and trade laws.

Unlike media-specific statutes of the United States, the environmental law of Mexico exists in a single broad statute. The environmental enforcement agency of Mexico, which is equivalent to the USEPA, is the Secretaria de Desarrollo Urbano y Ecologia (SEDUE), formed in 1982. While Mexico's law is comprehensive in scope and sets reasonable ecological standards, compliance is minimal because enforcement is minimal. SEDUE estimates that 52 percent of the nation's maquiladoras have generated hazardous waste and few have obtained basic operating licenses. Mexico simply does not have the fiscal or human resources to adequately enforce its comprehensive environmental law.

While it is impossible to predict what impact NAFTA may ultimately have, its passage is likely to attract even more industrial production facilities (such as metal finishers) to Mexico and further compound the compliance problem. This issue is not unique to

North America, but arises in any region with disparate environmental policies.

A.4.7 Future Trends

Based on the information reviewed in this section, the following observations can be made:

- Waste minimization programs that address metal plating operations will increase in number due to the toxic chemicals managed by this industry.
- These programs will be split among voluntary and mandatory programs, with mandatory programs being less "command and control" and more incentive driven.
- The overall regulation of metal finishers will continue to increase in scope and stringency, creating greater incentives for legitimate operators to pursue waste reduction/cleaner technologies and driving noncompliant operations to regions of minimal regulation or lax enforcement.
- International waste minimization currently focuses more on industrial and solid waste than does U.S. waste minimization.
- Small metal finishing operations appear to have special needs as they are forced to decide whether to pay the increasing cost of compliance, reduce waste generation, or become fugitive operations.

A.4.8 Sustainable Development

According to the United Nations World Commission on Environment and Development, the term "sustainable development" refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs. While the precise definition of the term is still the object of considerable international debate, consensus exists on several fundamental issues. Sustainable development requires a long-term perspective for planning and policy development; dictates actions that build on and reinforce the interdependence of our economy and our environment; and calls for new integrative approaches to achieve economic, social, and environmental objectives.

Sustainable development has emerged in recent years as a focal point for policy makers concerning the long-term economic and environmental outlook. The level of concern about sustainable development was made evident in 1992 at a United Nations Conference on Environment and Development. Representatives from 180 countries gathered at this conference to promote sustainable and environmentally sound development.

Many of the past and present USEPA programs have utilized tenets of sustainable development. USEPA, however, has not employed the concept as an overall policy framework or programmatic objective until very recently. The limited use of sustainable development concepts in USEPA policies is, in part, due to a lack of these concepts in its statutory mandates. It is generally agreed that statistically and scientifically credible environmental data and information are needed to measure progress toward environmental goals and sustainable development.

USEPA is implementing a program to gather and provide statistical information about the status and trends in the Nation's ecological systems. USEPA's Environmental Monitoring and Assessment Program is the first statistically based monitoring program to assess ecosystems on a national scale. The program is designed to advance the scientific knowledge of ecosystems and how these ecosystems are changing and responding to human activities.

A.5 Austria

A.5.1 Organizational Structure

Austria's responsibility for environmental protection is under the Ministry of Environment, Youth and Family Affairs. The Minister is responsible for setting waste generation rates and creating strategies for waste minimization.

According to the provisions of the Austrian Waste Management Act, the federal government's principle role is to set up technical standards for hazardous waste collection facilities. The provincial government gives consent as to which groups of waste require collection, and the municipalities make the detailed plan for when, where, and how the collection takes place.

<u>Regulations and Laws</u>

The Austrian waste management act influences waste minimization. Section 9 of the act requires legal permission for the installation and operation of plants, as well as for the modifications of old plants. Best available technology (BAT) is to be used. To gain permission, the description and amounts of waste and waste minimization strategy are required.

Firms with more than 250 people are required to employ a waste expert.

Similar to the German regulations, Austria has drafted a number of ordinances aimed at specific waste streams. Targets are set and it is up to those parties concerned to meet the targets. If the targets are not met within the specified time period, the government is free to set up compulsory measures.

Demonstration and Assistance

The Ministry of the Environment is in charge of task forces to facilitate specific waste management plans for several industry waste streams. These plans are meant to encompass waste avoidance, waste recycling, etc. These plans form the basis for any financial assistance. Members of these task forces come from Federal Chamber of Economy, relevant professional association, the Federal Environment Protection Agency, and industries.

Plans have been completed for the following waste streams or industry: paints and lacquers, wood preserving, tanning wastes (chromium), foundry, organic halogenated and non-halogenated, electroplating, garage (autos), medical, agriculture.

A.6 Canada

In 1990, the Canadian Government released its "Green Plan," which contains targets and schedules that will drive environmental initiatives within the federal jurisdiction for many years. The Green Plan outlines the National Waste Reduction Plan, which aims to reduce the amount of waste needing special treatment or disposal by 50 percent by the year 2000.

A.6.1 Organizational Structure

For the most part, the collection, management, and disposal of waste is under provincial and/or local legislation. Provincial governments are responsible for water, sewage treatment, waste collection, and disposal, as well as land-use planning.

The federal government provides leadership, support, and national action on hazardous and solid waste problems. In particular, the federal government does the following:

- Provides technical support, research, and data necessary for informed decision-making by consumers and industry (e.g., national packaging protocol)
- Promotes and develops national standards and guidelines (e.g., export and import of hazardous wastes
- Supports the development, testing, and demonstration of effective technologies.

Regulations and Laws

The key environmental legislation at the federal level is the Canadian Environmental Protection Act (1988). This act sets environmental quality objectives, guidelines, and regulations to prevent the contamination of water, soil, and air.

Current federal legislation that deals with wastes include the following:

- Ocean Dumping Regulations
- Contaminated Fuel Regulations
- Export and Import of Hazardous Wastes Regulations
- Storage of PCB Materials Regulations
- Chlorobiphenyl Regulations
- Transportation of Dangerous Goods Regulations
- Federal Mobile PCB Treatment & Destruction Regulations.

Each province has complimentary waste management legislation as it applies to areas under their jurisdiction.

Fiscal Measures

Fiscal measures are used by provincial governments to promote environmental protection. User charges and taxes on treatment and disposal of wastes and product charges and taxes, including deposit refund systems on beverage containers, are used.

Demonstration and Assistance

To meet the targets set out in the National Waste Reduction Plan, the federal government, in conjunction with provincial and territorial governments, the private sector, and community groups, will promote the four R's of waste management—reduce, reuse, recycle, and recover—and will:

- Through the National Packaging Protocol Program, reduce waste from packaging materials by 50 percent by the year 2000.
- By 1994, for other components of the waste stream, develop national standards, codes, policies, and regulations for the reduction, reuse, and recycling of wastes.
- Support technological innovations aimed at waste reduction, recycling, and reuse.
- Support community action through an expansion of the Environmental Partners Fund.
- Provide information to individuals and businesses through new and existing programs.
- Commit the federal government to reducing waste from its own operations by 50 percent by the year 2000.
- Expand the National Waste Exchange Program to improve the market opportunities for the reuse and recycling of industrial and large-volume wastes.

A.7 Denmark

A.7.1 Organizational Structure

The Ministry of Environment is responsible for environmental protection, including waste management; however, the executive responsibility for waste management lies with the municipalities.

In accordance with the Environmental Protection Act, the municipal authorities are responsible for directing waste to appropriate treatment or disposal facilities and for the adequate provision of such facilities. The authorities are also responsible for the practical aspects of household waste collection, the separate collection of glass and paper from households for recycling, and the collection of paper from trade premises and public institutions for recycling. These duties are either performed by the municipal services themselves or by private contractors on the behalf of the municipalities.

Action plans for both cleaner technology and waste and recycling (see below) are administered by the National Agency of Environmental Protection. The funding of individual projects, however, is the responsibility of the Danish Recycling and Cleaner Technology Council. This council comprises representatives from the Ministry of the Environment, industrial organizations, municipalities, counties, nongovernmental organizations, and two experts on recycling and cleaner technology.

Regulations and Laws

Several statutory orders under the Environmental Protection Act address waste disposal:

- Reuse of packaging for beer and soft drinks
- Recycling of newspapers/magazines and glass from private households
- Recycling of paper/board from commercial and institutional sources
- Recycling of food waste from catering centers
- Recovery of slags and chemical waste.

The legislation framework for environmental protection has been revised recently. Not only does the Act call for preventing and reducing pollution of the air, water, and earth but also the waste of raw materials and energy through the adoption of cleaner technology.

Pollution permits are an integral part of this Act. The environmental authorities, either county or municipal, explicitly state the conditions for polluting, including industrial process used, waste amount, water discharges, air emissions, and waste handling for listed activities.

The overall waste management policy for 1993-1997 is described in two separate action plans, one for waste and recycling and the other for cleaner technology. According to these plans, the adoption of cleaner technology is expected to stabilize waste quantities by the end of the 1990's. Increased waste recycling is expected to produce a 50-percent reduction in waste sent for final disposal.

In the new Environmental Protection Act, the Minister for Environment can negotiate "voluntary agreements" with industry.

Fiscal Measures

In Denmark, financial instruments concerning waste minimization are taxes, duties, and fees, as well as grants and subsidies.

There is a duty on raw materials. Also, there are several duties on waste (not including materials for recycling or recovery), both on waste that is incinerated and on waste that is disposed of in landfill.

The treatment of sewage is also meant to be self sustaining by users. Therefore, charges differ from user to user depending on the contribution of polluted effluent.

While previous recycling plans used subsidies to promote new collection and processing schemes, future solutions must be based on market-oriented tools. Government subsidies for capital investments are, therefore, no longer granted. Local services, such as waste collection, separation, and treatment, must become self supporting. Private companies will be encouraged to finance some collection and processing schemes in the future. These investments may need to be financed via the product price.

Demonstration and Assistance

In the cleaner technology action plan of 1993-1997, various industrial sectors (e.g., slaughterhouses, dairies, fish processing, chemical) and products (e.g., building materials, furniture) are targeted for sector mapping projects, development of technology, research studies, etc., and these are largely financed through the budgets for the action plans. Metal plating is not addressed specifically.

The Ministry of Industry also administers a program to support the commercial exploitation and development of environmental technology, including cleaner technology. The current program runs from 1991 to 1994.

In waste management and recycling, regular followup measures on material flow analyses, etc. is being studied in order to provide feedback for implementing targets and/or voluntary agreements. So that recycling is both economic and environmentally viable, more development on collection systems and treatment and processing plants are planned. Investigations will also be carried out to identify recycling options or needs for special treatment with oil and chemical wastes.

A.8 Finland

A.8.1 Organizational Structure

The focal points for waste management are the Ministry of the Environment (MOE), the Provincial Governments (PGs), and the municipal authorities. The Waste Act (came into force on January 1, 1994) covers nationwide and provincial waste planning, which is the task of the MOE and the PGs.

Regulations and Laws

The Waste Act aims at promoting sustainable development through the rational use of natural resources and through preventing and abating hazard and inconvenience to human health and the environment caused by waste. Regulations on the prevention of waste generation and on the reduction of the amount and hazard of waste are introduced in the Act. The government (Council of State) may issue general regulations on prohibitions and restrictions and other general regulations related to products and wastes of these products.

Waste permits are required for industrial and professional waste recovery and disposal, as well as for professional collection of hazardous wastes. Also larger industrial plants, power plants, central heating plants, and remediation of contaminated sites need a waste permit according to the Waste Decree.

Fiscal Measures

The government has instituted a surtax on some items. Disposable packaging for beverage containers are charged. This has enabled Finland to maintain a high use of reusable containers. Only 5 to 8 percent of all beer and soft drinks consumed are packaged in one way containers. There are also surtaxes on fuels, fertilizers, and oil products, including waste oil.

According to the Waste Act, municipalities have the right to charge the costs for waste management efforts that they organize and must charge full costs for waste disposal activities that they organize. This is expected to have a positive effect on waste minimization.

Demonstration and Assistance

The MOE provides assistance for experimental projects aimed at waste avoidance or recycling.

Under the Department of Trade & Industry, grants may be given to projects and product planning related to clean technology.

The MOE also finances studies in various branches of industry on best available technology. Studies have recently been completed on car repair and engineering industry, as well as on the paint and pharmaceutical industries.

The new Waste Act expands the concept of waste management to cover production and full life cycle of products. In order to fulfill the aim of sustainable development, the government (Council of State) may issue, under certain conditions, general regulations on:

- Production and manufacturing processes
- Limitations in or prohibition against use of products
- Obligations of manufacturers and importers to arrange management of wastes generated from their products.

With the entry of Finland into the European Economic Area Treaty from 1 January 1994, close attention has to be paid to EC directives.

A.9 Germany

A.9.1 Organizational Structure

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is responsible for all fundamental matters of environmental policy, including transfrontier co-operation, water management, waste management, air management, noise abatement, environmental health, protection against substances, nature conservation, soil protection and contaminated sites, safety of nuclear facilities and protection against radiation, and disposal of nuclear matters.

The principal agencies that support the Ministry of the Environment include:

- The Federal Environmental Agency, which provides scientific advice on drawing up legal and administrative positions and regulations in the fields of air pollution control, noise abatement, and waste and water management, as well as general aspects of environmental protection. The Agency collects environmental data and is responsible for information dissemination and outreach to the public and for implementing and enforcing provisions contained in the Chemicals Act, the Pesticides Act, and the Gene Technology Act.
- The Federal Research Centre for Nature Conservation and Landscape Ecology, which is responsible for research and development and for the progress

of scientific concepts for the protection and management of nature reserves and specially protected areas.

- The Federal Office for Radiological Protection, a new body that is responsible for implementing and enforcing provisions contained in the Atomic Energy Act and the Precautionary Radiological Protection Act.

The German Constitution determines that the Lander (Provinces) bear responsibility for the implementation of environmental protection laws. The Lander determines the precise institutional forms of enforcement, which may vary among them. Often, tasks are delegated to lower levels of Lander administration or to the municipal level.

The administration of environmental protection in the Lander is structured according to environmental sectors: water, waste, air, and nature conservation. At the local level (municipality), typical tasks carried out are urban traffic planning and regulation, municipal waste management, cleanup of contaminated soil, waste water management, and noise protection.

Regulations and Laws

Germany has enacted legislation affecting both industrial and municipal solid waste (MSW). In 1986, a new waste avoidance and management act was adopted. Under this act, statutory regulations could be implemented if voluntary targets did not work. In 1987 and 1989, there were ordinances on waste oil and halogenated hydrocarbons. These products now require separate collection, reacceptance of used products by producers, and distributors for recycling or disposal. These new ordinances brought new responsibility to the generator of the waste.

German law requires certain wastes (e.g., organic solvents, and other organic liquids) to be destroyed, and these wastes cannot be legally disposed of on land. There is also very stringent design and monitoring requirements for landfills. This has greatly increased the cost of disposal for the metal plating industry, as well as for other industries. For example, western Germany landfill prices for metal sludges, oily sludges, and asbestos were roughly double the median price in the rest of Europe.

The German federal air pollution law has general provisions for the protection of the environment and for the minimization of toxic emissions. To accomplish specific goals, ordinances and regulations are promulgated under the law. The most comprehensive and well known law is the TA Luft. The TA Luft spells out source-specific emissions standards for total particulate matter, as well as for certain metallic components of the particulate matter. In addition, there are emission limits for 12 inorganic and 145 organic gases (which also impact metal platers). The substances are grouped into different classes according to general level of toxicity, with each class having a different allowable emission level. The TA Luft contains some general emission control provisions. It requires that state-of-the-art pollution control technology be used. Also, all plant workers are required to undergo practical and theoretical training in resource recovery.

Fiscal Measures

Currently, three Landers have imposed a surcharge on industrial waste generators. The German government is proposing a federal waste charge, where a portion of the money would be directed at helping the new Lander deal with the waste problems created in the past. Deposit schemes for containers, direct charges for household waste collection, and disposal are measures used in some Lander.

Demonstration and Assistance

The government provides aid for small and medium-sized enterprises (SMEs) to help them reduce wastes. For example, low-interest loans are available for up to 60 percent of investment costs of technologies for cleaner production and products. Also, the German government and the Confederation of German Industry act together to provide advice and some professional consultation services at no charge to SMEs seeking ways of reducing waste generation.

There are also requirements for reporting quantities of waste generated.

A.10 Italy

A.10.1 Organizational Structure

The Italian Ministry of Environment (MOE), created in 1986, is responsible for protecting the environment. With waste management, regulations and enforcement are shared with the Ministry of Industry and the Ministry of Health.

Waste minimization responsibility rests primarily with the MOE; however, the Ministry of Industry also has a coordinating and funding role in this area, principally oriented at creating incentives for the introduction of clean technologies.

A Commission on Industry and the Environment was established in 1990 with the specific aim of identifying forms of sustainable development, including, of course, reducing waste generation. The members of this commission include scientists and technologists from the industry and environment ministries.

Regulations and Laws

Law 441, which came into force in 1987, was the first law to permit the application of waste minimization in Italy. Article 14 establishes that "Industrial companies which intend to modify their production processes in order to reduce the quantity of the hazard level of the waste produced or to encourage recovery of the materials are, provisionally, to be given priority for benefits under Article 14ff of Law 46 of 17-02-82..." Furthermore, the law indicates that the changes in production processes that also bring about energy saving are also eligible for contributions from the Ministry of Industry, Commerce and Trade together with the Ministry of the Environment under Law 308 of 29-5-82.

Law 475 of 1988 sets out a number of regulations for industrial waste treatment that encourage waste minimization, particularly the post-consumption phases. Article 9(iv) of this law calls for the establishment of three authorized consortia for recycling packaging used for liquids (glass, metal, plastic, and composite materials). Minimum recycling quotas have been established—50 percent for glass and metals and 40 percent for plastics and coupled materials. Energy and/or heat recovery from this waste cannot exceed 50 percent of the established objective.

Article 9(v) also mandates the establishment of a consortium for spent lead batteries, which are to be collected separately and recycled.

In 1990, another resolution granted financial assistance from the Technology Innovation funds (Law No. 46 of 17-02-82) to those programs with environmental objectives (e.g., clean technology and end-of-pipe technologies).

In terms of post production interventions, DL 443, issued in the second half of 1993, encourages both reuse in production processes and combustion of production and post-production consumption residues through the establishment of a simplified authorization procedure. This authorization covers waste collection, stockpiling, and transportation.

Demonstration and Assistance

The MOE has developed voluntary agreements with certain industry sectors aimed at encouraging the use of clean technologies and waste minimization.

In the second half of 1993 under the Three Year Program for Environmental Protection, the MOE organized an information program on waste management, principally aimed at public bodies, local authorities, small enterprises, and private industrials. This program is designed primarily to identify measures suitable for correct waste management, particularly in terms of waste reduction.

Waste streams that either represent a large volume or are highly toxic are being identified and studied in collaboration with the Commission of the European Community. This should provide better information on the origin, type, quantities, characteristics, and hazardousness of the waste. From this information, realistic possibilities for reuse, recycling, and recovery can be determined for both production and post-consumption waste.

A.11 Norway

A.11.1 Organizational Structure

Waste management in Norway is ultimately the responsibility of the Ministry of Environment (MOE). The MOE, however, delegates some of that responsibility among the State Pollution Control Authority (SFT), the County Departments of Environmental Affairs, and the municipalities.

The MOE ensures environmentally sound treatment of waste and establishes goals, strategies, and classifications. SFT is a directorate under the MOE with a role in enforcing regulations on pollution, waste management (hazardous and non-hazardous), and noise. It also has the responsibility for regulating waste incineration, issuing any other waste management guidelines for the county departments and administering subsidies for waste minimization projects. The county departments are responsible for regulating municipal landfills and other facilities and giving information to the municipalities regarding waste management issues. The municipalities are responsible for providing a collection and treatment system for municipal waste.

Regulations and Laws

Two significant acts affect waste minimization in Norway—the Pollution Control Act and the Product Control Act.

The Pollution Control Act aims to protect the external environment from pollution by trying to reduce the existing pollution, as well as promoting better treatment of waste. The law covers the following legal requirements regarding waste:

- Permits for incineration and landfilling, as well as for various polluting industries
- Imposition of demands for waste reduction and recycling in private industry and municipalities
- Requirement for waste plans from the municipalities, including requiring municipalities to charge full costs for waste management activities.

The Pollution Control Act also contains four specific regulations regarding hazardous waste. These regulations cover specific waste requirements on hazardous products and processes, as well as the import and export of hazardous wastes.

The Product Control Act is meant to prevent products causing damage to health or environment (e.g., pollution, waste, noise). This law includes legal permission to make decisions concerning return and deposit arrangements, recycling, and treatment of waste.

Demonstration and Assistance

Subsidies are given to both industry and municipalities. Subsidies to industry encourage clean technologies projects, and subsidies to municipalities are for investment in material recovery facilities and other separation schemes.

SFT is also striving to provide better statistics and make those statistics available to the public. They are also initiating information campaigns on waste reduction and recycling.

The government is working with industry in achieving voluntary agreements on waste minimization as much as possible but will use legal measures if needed.

A.12 United Kingdom

A.12.1 Organizational Structure

The Department of the Environment (DOE) has a number of functions, one of which is responsibility for environmental protection. The Department's Environmental Protection Group inter-alia both develops policy and legislation on waste and enforces parts of the legislation through Her Majesty's Inspectorate of Pollution (HMIP). HMIP is responsible for enforcing laws relating to pollution from industrial processes. Responsibility for enforcing other waste management legislation rests with other agencies, primarily the National Rivers Authority (NRA) and the Waste Regulation Authorities (WRAs). The NRA is not part of the DOE but is sponsored by it. It is responsible for the control of pollution of the aquatic environment. The WRAs are local authorities responsible for enforcing legislation relating to the management of controlled waste. The government is considering bringing HMIP, NRA, and the WRAs together in one organization—The Environmental Agency—possibly in 1995. At present, however, this is only a proposal and much preparative work remains.

The DOE is also responsible for encouraging domestic waste recycling and minimization. The Department of Trade & Industry (DTI) is responsible for encouraging sound waste management practices, especially waste minimization and recycling, in the industrial sector. The DOE, the NRA, and the DTI all have substantial research programs to underpin their policies and activities on the management of waste.

Regulations and Laws

The key regulatory measure for waste minimization is part 1 of the Environmental Protection Act of 1990. This introduces the concept of IPC, which applies to the release of pollutants to air, water, and land from certain processes. Certain processes will have to apply to HMIP and be required to meet statutory emission standards.

Grants are also available to support the development of clean technology. The Government will pay up to 50 percent of the costs for suitable projects.

DTI has produced a booklet of case studies that emphasize the economic benefits of waste minimization through the adoption of cleaner technologies.

The adoption of the Environment Protection Act of 1991 significantly changed how industry operates many of manufacturing processes in the U.K. The metal finishing industry was directly affected because of certain prescribed activities, including industrial cleaning and finishing. To operate many of the prescribed processes, a company needs to obtain a license for which there is a fee and annual policing charge. To obtain and keep this license, the company must demonstrate that the process meets the environmental standards. The legislation allows for regulations to be gradually tightened to take into account emerging technologies, such as cleaner technologies.

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Endnotes

[1] For descriptions of specific tools for developing and implementing pollution prevention at the facility-level, see Appendix B.

[2] Growing international concern over stratospheric ozone depletion culminated in an international agreement known as the Montreal Protocol on Substances That Deplete the Ozone Layer. The Protocol has been adopted by more than 60 countries and took effect on January 1, 1989. In 1990, due to mounting scientific evidence indicating greater than expected stratospheric ozone depletion, the parties to the Protocol met in London and agreed to accelerate the phaseout schedules for the substances already controlled by the Protocol. They also added phaseout requirements for other ODS, including methyl chloroform, carbon tetrachloride and CFCs.

APPENDIX B – IMPLICATIONS AND EVALUATION OF POLICIES

B.1 Introduction

This section presents an overview of the effects of pollution prevention policies on waste generation in, and the environmental impacts caused by, metal plating industries.[1] The discussion examines these effects in historic, current, and future terms. It also aggregates the information presented in the previous section into broad categories of policy options and examines the implications of these basic categories of pollution prevention policies.

As USEPA points out in its report entitled *Sustainable Industry: Promoting Strategic Environmental Protection in the Industrial Sector: Metal Finishing Industry*, Office of Policy, Planning, and Evaluation, USEPA, June 1994 (hereinafter referred to as SIP Report), a key step in characterizing the selected industries is to identify the factors and barriers that influence corporate decision-making and environmental performance. These factors represent the key leverage points for an industry such as metal finishing. It is important to understand the regulatory, informational, economic, or other factors that provide the greatest incentives and impose the largest barriers to improved environmental performance. These are the factors that influence investments in pollution prevention in the metal finishing industry.

The following sections will briefly characterize the metal plating industry (including trends), describe the impact pollution prevention measures have had on the metal finishing industry, and identify the barriers to improved environmental performance in this industry. A summary of the section's highlights is provided in **Exhibit B-1**. These sections will draw on conclusions from an examination of the U.S. and international policy sections, as well as a summary of USEPA's findings in the SIP Report.

B.2 Industry Characterization

It is clear from Section 3 of this report that cleaner technologies and products already exist in the metal finishing industry as a result of extensive government and trade association cooperation on product and process technology development and technology transfer, as well as military research and development. These technologies do not address every environmental issue encountered by the metal plating industry, but they do provide the potential for improvement in many areas. The availability these technologies is an important factor in promoting waste reduction.

A second fundamental point is that the metal finishing industry is very diverse in terms of processes (e.g., electroplating, plating, polishing, anodizing, and coloring) and size of operations within the industry. Metal finishing "job shops" tend to be small and generally have fewer resources available to address environmental concerns. In addition, they are usually less specialized than many captive operations. The captive metal finishers tend to have greater access to financial and organizational resources and, consequently, tend to be more proactive with their environmental programs.

Due to the diverse nature of this industry, it is useful in assessing policy implications to subdivide the metal finishing industry to better understand the policy implications and barriers to waste reduction. For example, the USEPA SIP Report subdivided the metal finishing industry into four groups or "tiers." These groups are characterized according to environmental performance and differ according to key factors that influence decision-making, as described in **Exhibit B-2**.

Some metal finishers from groups 3 and 4 have an incentive to remain operational despite declining profits due to potentially high environmental cleanup costs associated with shutting down and liquidating a business. Since these firms lack the money or motivation to improve environmental performance, they continue to pollute and represent a problem for the environment. These operations are typically not pursuing waste reduction and may require innovative policies to achieve meaningful change.

B.3 Impact of Policies

As discussed in the previous chapter, numerous waste minimization policy initiatives are currently being pursued at all levels of government in most major industrialized countries. This represents a fundamental shift in the focus of environmental policy toward reducing the regulatory compliance and liability burdens faced by industry, while increasing operational efficiency and protecting the public.

As discussed, many of these waste minimization initiatives affect the metals plating industry, although most, quite understandably, are much broader in scope. Overall, these waste minimization policies can be grouped into voluntary and mandatory programs. Voluntary programs include those that rely on establishing waste reduction goals, information and technology transfer, grants, voluntary participation, incentives, or public sentiment to achieve waste minimization objectives (e.g., Nordic Council vs. European

Exhibit B-1. Policy Approaches and Implications

Policy Approach/ Mechanism	Application to Metal Finishing	Policy Implications
Direct Regulation	• Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act regulations that directly impact the cost of generating, treating, and disposing of wastes in the metal finishing industry.	• Increase the cost of generating waste and create greater financial incentives for industry to improve efficiency and reduce waste generation.
Planning Requirements	• Pollution Prevention Act reporting and State planning requirements apply to broad categories of industries, including metal finishing operations.	• Force industry to examine opportunities for waste reduction without imposing inflexible goals.
Reporting	• Pollution Prevention Act and State reporting requirements monitor waste reduction activity.	• Prompts waste reduction activity and provides a measure of activity and progress.
Enforcement	• ESP SEPs and analogous State Programs.	• Provide additional incentive for industry subject to enforcement action to pursue pollution prevention as means of coming into compliance and prompting future compliance and efficiency.
Financial Incentives	• Federal and State grants, as well as tax incentives and market-based regulatory initiatives, affecting numerous industries, including metal finishing.	• Promote the development and dissemination of waste reduction information. • Create financial incentives for metal finishing industry to pursue pollution prevention.
Technology Transfer	• Pollution Prevention Act and State initiatives promote development and sharing of pollution prevention information for a broad spectrum of industries.	• Provides the data base for large and small metal finishers to initiate waste reduction initiatives.

Community Directives). Mandatory policies include direct regulation (e.g., effluent limits or hazardous waste listings that create strong incentives for reduction, as well as waste reduction planning and certification requirements), the use of permitting authority, and the imposition of supplemental environmental projects (SEPs). No waste minimization programs have directly mandated specific industries to change their operations and to achieve specified goals, but there are signs that some programs (e.g., that National Emissions Standards for Hazardous Air Pollutants under the U.S. Clean Air Act) may move further in this direction if control technologies cannot achieve requisite levels of environmental protection. In addition, restrictions imposed under programs not aimed at the metal plating industry, such as the ozone protection requirements, may affect the plating industry by restricting its access to certain chemicals.

Given that these waste minimization policies are relatively new, most governments are attempting to foster a new waste reduction ethic through less prescriptive policies, which rely in part on the inherent attractiveness of prevention-oriented policies for industry (e.g., reduced regulation, increased efficiency). Governments and industry both understand that waste minimization policies are very attractive from a cost-benefit perspective when compared to traditional regulatory approaches (i.e., command and control).

Exhibit B-2. Metal Plating Groups/Key Decision-Making Factors

Tier	Group Characteristics	Decision-Making Factor
I	Firms constantly in compliance with regulatory requirements and proactive in making environmental improvements beyond baseline compliance.	Firms in the first group are driven by recognition and pride in industry performance. These firms tend to be forward looking and are motivated by anticipated payoffs from strategic environmental investments.
II	Firms with the primary objective of complying with existing regulations. These firms either lack motivation or resources to improve beyond this baseline level.	Firms in the second group are driven more by a strong desire to achieve and maintain compliance with federal, State, and local environmental requirements. This second group represents the largest segment of the industry.
III	Firms that consist of old and outdated shops that are not profitable enough to justify investments in new pollution controls. Many of these firms would like to close, but remain open for fear of cleanup liability.	The old outdated shops in the third group have a strong fear of liability. They have little interest in improving their environmental performance because they lack the capital, information, and often even the space to do so.
IV	Firms that are consistently out of compliance and make no attempt to improve yet escape enforcement attention. These "renegade" firms are not substantial competitors but compete with other firms by avoiding the costs of environmental investments.	The renegade shops have no incentive to improve. They do not fear enforcement because they are difficult to track down. These firms profit by undercutting firms in the top groups.

Overall, waste minimization policies that affect the metal finishing industry are continually being expanded. As discussed previously, these policies take several forms. However, these policies typically do not dictate the terms of waste reduction; rather, they attempt to create waste reduction incentives, develop and share waste reduction information, and promote reduction-oriented thinking. Such polices are not as prescriptive as they might be due to a hesitancy on the part of regulators to meddle with the manufacturing process itself, as well as their understanding that, in many instances, rigorous regulatory schemes already create strong incentives for waste reduction. In addition, such regulations are generally being made more stringent across nearly all media. These incentives do not apply to operations in group 4, because these firms tend to disregard applicable regulations. Hence, group 4 operations (and some group 3 operations) do not participate in waste reduction activities with the same vigor as groups 1 and 2.

Waste reduction policies are a relatively recent phenomenon, and effort is being spent examining how such policies can be implemented most effectively, as well as how such policies promote reduction among small or minimally compliant companies that may not have the same needs or incentives as larger operations. Industry appears to be sharing waste reduction information and assessing the costs associated with process or material changes, the availability of effective technology, and the time necessary for implementation. However, communication problems still exist within developing countries and smaller job shops. Given the diversity of the metal finishing industry, progress will vary dramatically.

B.3.1 Cumulative Effect of Existing Policy on Volume and Hazard Reduction

For several reasons, it is difficult to quantify the effects of existing waste minimization policies on the metal plating industry. First, it is difficult to measure waste reduction and, as a result, many policies are in place that lack mechanisms to measure their effectiveness. Without these mechanisms, limited data have been generated documenting waste minimization. A second factor that makes quantifying effects difficult is the existence of many different policies at different levels of government that affect production, waste generation, and waste management. Finally, assessing the effects of waste minimization policy on metal plating is complicated by the difficulty of establishing cause and effect (i.e., that waste reduction policies caused any reduction in waste generated). All of these issues require additional attention. Yet, despite these obstacles, some preliminary assessment can be performed.

Within the United States, the most broadly used indicator of toxics loading to the environment is the

Toxics Release Inventory (TRI). The TRI measures releases to the environment of specific chemicals from specific industries (designated by Standard Industrial Classification [SIC] codes). The TRI applies to U.S. companies only.

According to progress reports assessing the effectiveness of USEPA's 33/50 program (described in Section 4), releases and transfers of 33/50 chemicals from all U.S. fabricated metals companies (1,525 reporting) decreased by 31 percent between 1988 and 1991 (based on TRI data).[2] Nine of the chemicals monitored under the 33/50 program are typically generated by metal plating operations.[3] For those fabricated metals companies that have committed to participate in the 33/50 program, this reduction was an even more significant 41 percent. Note that companies participating in the 33/50 program typically are the larger, more progressive companies within groups 1 and 2.

Since the TRI data include movement of waste off-site for treatment or disposal, the data indicating an industry-wide reduction of releases of 31 percent suggest that metal plating operations are reducing the quantity of toxic constituents generated. Such reductions are arguably the result of a mix of waste minimization efforts. However, beyond attesting to the effectiveness of the public reporting requirements imposed under the TRI, these data do not identify any specific waste minimization policy as more effective than any other.

Reporting required under the TRI has made many industries aware, often for the first time, of the character and magnitude of their environmental releases. This awareness has prompted all industries subject to TRI requirements to seek to reduce these releases, and these reductions have taken many forms. Unquestionably, the vigorous promotion of waste minimization policy has contributed to these reductions. However, other than acknowledging that the TRI has created a major incentive for industry to reduce releases, the industry-wide data are not sufficient to correlate the magnitude of these reductions with specific waste minimization policies.

In contrast, the additional incremental reductions achieved by those metal fabricators participating in the 33/50 program suggest that a well conceived voluntary waste minimization program can be effective in reducing toxic releases. These companies, which consist of 175 companies that made commitments to participating in the voluntary program, achieved a 10 percent greater reduction than others companies in the industry. Note that the target of the 33/50 program is reductions of 33 percent by 1992 and 50 percent by 1995. Thus, the metal plating industry (as represented by SIC 34) has exceeded the reduction goal by 8 percent, 1 year early. Considering its voluntary nature, this must be viewed as an effective program (at least for group 1 and 2 operations). Key characteristics of the 33/50 program include its ability to get participants to commit, at a senior level, to pursuing waste reduction objectives, the availability to the TRI as a mechanism to identify inefficiencies and measure progress, and the flexible environment created that allows companies to use in-house expertise and available waste minimization resources as the situation warrants.

Generally, the TRI data indicate that the more progressive portion of the metals fabricating industry has substantially reduced its releases over a relatively short period of time. Hence, some combination of waste minimization policies (and perhaps other policies as well) is working for the proactive sector of the industry. As direct regulation of the metal plating industry or chemicals used by this industry increases, the incentive to achieve additional waste reductions will also increase. For marginal operations, policy approaches may need to link stringent enforcement or streamlined regulatory requirements with waste reduction opportunities to facilitate more environmentally sound behavior.

A final point raised by the TRI data concerns the quantity of releases from the metal fabricating industry that are still occurring. In 1991, all U.S. metal fabricators reporting in the TRI released 74,148,919 pounds of the 17 chemicals targeted under the 33/50 program. Clearly, this suggests that significant opportunities for additional waste reductions remain.

With regard to the degree of hazard posed by wastes generated and released by the metal plating industry, little quantitative data are available. The significant decrease in emissions of 33/50 chemicals by the metal fabricators suggests that some reduction in hazard has occurred. For example, a recent study indicates that cyanide and chlorinated solvent usage in U.S. plating shops has decreased by 50 and 25 percent, respectively, since 1980. Many plating shops have completely eliminated the use of cyanide, and, with continued improvements in non-cyanide metal finishing, it is reasonable to expect nearly complete substitution for cyanide processing within the next 10 to 20 years. Certainly, such changes will reduce the hazard posed by metal finishing, although quantifying such reduction may still prove challenging.

B.4 Barriers to Waste Minimization

The most significant barriers to waste minimization, as evidenced from the preceding sections and described in the USEPA SIP Report, are discussed in this section.

B.4.1 Regulatory and Institutional

Inconsistency in existing regulatory requirements and enforcement actions at the international, federal, State, and local level creates uncertainty and possible competitive imbalances throughout the industry. This tends to create distrust of the regulating industry and inhibits communication. A large number of metal finishing firms face significant environmental liabilities and clean-up costs if they discontinue operations and attempt to liquidate their operations, which eliminates any access to outside capital resources that might be used to fund pollution prevention projects.

B.4.2 Economic and Financial

Many job shops lack the personnel and financial resources to look beyond baseline compliance and examine innovative techniques to prevent pollution. In addition, there is a clear lack of full cost accounting techniques in most countries. As a result, the evaluation of the full cost-benefit impacts of waste minimization are not realized and, therefore, not implemented.

B.4.3 Technological

Smaller shops are not active in trade association activities and are not aware of changes in product/process technology, including inexpensive, cost-effective cleaner technology changes that can dramatically improve environmental performance. In some countries a lack of resources to enforce statutory and/or regulatory compliance creates no incentive for firms to look for cleaner technologies, and there is a lack of investment in basic research on industrial waste minimization.

B.4.4 Industrial and Managerial

Industrial managers do not have a clear understanding of the financial and other benefits associated with waste minimization. In addition, adoption of cleaner technologies often carries a greater degree of uncertainty and risk than end-of-pipe technologies. This often creates a reluctance to substitute for cleaner products or processes.

B.4.5 Socio-Cultural

There are significant psychological barriers to shifting to cleaner technologies. Some companies would rather not risk a newer technology when it is easier to simply remain in baseline compliance. They fear tighter regulatory standards and negative government impacts on production, as well as enforcement actions and loss of trade secrets when "confidential" information is released.

B.5 Summary of Policies and Trends

International policy options to encourage or enforce waste minimization take many forms. For example, many countries utilize regulatory programs. The regulatory process is complex, and each regulatory program tends to reflect a process of conflict and negotiation among interested parties. Two forms of regulatory style toward the industrial sector are used. One form relies on specified and precise rules, such as the U.S. Clean Air Act regulations. A second compliance style seeks to obtain compliance with legislative goals using flexible guidelines, allowing for situational factors, such as the European Community's IPPC. No country appears to rely totally on one approach or the other.

Economic instruments have been used internationally to create incentives or disincentives through tax provisions, subsidies, fees for permits, etc. The main purpose of these economic instruments is to create a behavioral change by creating a financial punishment or reward.

Information and training are critical elements necessary to provide industry with the knowledge that is essential to implementing waste minimization. Most countries have programs that provide for information and training (e.g., Nordic Council) and citizens from more than a dozen OECD countries have logged-on and utilized electronic information/technology transfer from the International Cleaner Production Information Clearinghouse (ICPIC) or the Pollution Prevention Information Exchange System (PIES).

Ecolabeling programs have been used in many OECD countries (e.g., Germany) to provide an indication of the most environmentally benign product. The market advantage of a product having an approved eco-label often acts as a stimulus for cleaner production (e.g., Clean Air Act labeling requirement).

Voluntary agreements are a pledge to achieve certain environmental goals (e.g., USEPA's 33/50 program) and have met with great success. These have advantages over command and control type regulations because they may be implemented rapidly and they tend to be more reflective of mutual cooperation between industry and government.

In addition, liability impositions impose a strict liability for any damage due to environmental causes. These can act as a strong incentive to prevent the release of toxics to all environmental media. Africa recently negotiated the Bamako Convention, which calls for strict and unlimited liability for hazardous waste damages. The EC has made similar proposals, and liability impositions appear to be a growing international trend.

While historical problems still remain and have prevented full utilization of waste minimization methods, progress has been made in most countries, particularly among companies in groups 1 and 2. These historical problems have been characterized by many observers in the following ways: the generation of waste has been regarded as peripheral to the production process; regulatory efforts to manage the problem have focused on end-of-pipe treatment; regulations have taken a media-specific approach, often resulting in the transfer of toxics from one medium to another; the true costs of waste management has been externalized.

Nevertheless, many countries have begun to move beyond these outdated historical views and have attacked the problem through a variety of policy options. Most countries have based waste minimization policies on laws and regulations, many of which focus primarily on solid and municipal waste minimization. Even in the more proactive countries that have adopted policies to address industrial waste, minimization policies have focused on larger firms. It is apparent that the smaller job shops are escaping a great deal of scrutiny around the globe. Another international trend is that many countries abdicate responsibility to State or local levels, often resulting in inconsistent regulation of wastes. In addition, it is increasingly clear that despite the primary focus on domestic waste minimization policy, international policies such as trade (e.g., the North American Free Trade Agreement) also have an impact on international environmental policies.

While most OECD countries rely on many of the policies described herein, two trends stand out as rapidly growing. These trends are sustainable development/sustainable industry, which relies on an in-depth review and understanding of the unique features of each industry in order to remove barriers to technologies such as pollution prevention. Also, the imposition of strict liability policies looms on the horizon, if more environmental progress is not evidenced in the near term. Both of these trends will have a greater effect on the smaller "job shops" that tend to escape notice and enforcement.

Endnotes

[1] In preparing this discussion, selected information was drawn from the U.S. Environmental Protection Agency's (USEPA) Sustainable Industry Project (SIP). This project represents a new approach to developing environmental policy within the United States because it requires industrial environmental policies to be developed based on an in-depth understanding of the characteristics and decision-making factors unique to each industrial sector.

[2] Based on release data for the fabricated metals industry, SIC 34. Due to the diversity of the metal plating industry, this SIC does not represent the entire industry. However, it is provided here because it represents a significant portion of the industry and it is representative of reductions in releases that may be achieved by metal plating.

[3] Cadmium/cadmium compounds, carbon tetrachloride, chromium/chromium compounds, cyanide/cyanide compounds, methylene chloride, nickel/nickel compounds, tetrachloroethylene, 1,1,1 trichloroethane, and trichloroethylene.

Appendix C—U.S. Federal and State Pollution Prevention Policy/Plans

C.1 Federal Pollution Prevention Statutes

The United States has traditionally enacted environmental legislation that tends to focus on pollution control targeted at specific media. With the passage of the Pollution Prevention Act (1990) and the continuing reauthorization of the major media statutes, this focus is shifting more and more toward pollution prevention. At the same time, implementation of the major U.S. laws is also shifting towards preventative approaches where possible. The discussion below summaries key prevention-oriented requirements of select major U.S. laws.

C.1.1 The Pollution Prevention Act

A growing trend and national shift toward reducing rather than treating waste led to the enactment of the Pollution Prevention Act of 1990 (42 USC 13101-13109)(PPA) in October of 1990. In its findings, Congress stated that source reduction opportunities often went unexploited because of a variety of factors including the fact that existing regulations and industrial resources were focused on treatment and disposal, applicable regulations did not require or address a multimedia approach to pollution prevention, and there was a lack of essential information on source reduction technologies that industry needed to overcome institutional barriers to source reduction.

This statute established in the United States a national policy that pollution should be prevented or reduced at the source whenever feasible. Pollution that cannot be prevented should be addressed through recycling programs, and if these options are not viable, then pollution should be treated and disposed in an environmentally protective manner.

The PPA directed EPA to establish a source reduction program that collects and disseminates information, provide fiscal assistance to the states, and become the primary federal agency responsible for implementing the Act. The EPA issued a Pollution Prevention Strategy in February 1991 (56 *FR* 7649) to clarify its pollution prevention mission and objectives to be accomplished. The Strategy is designed to accomplish two primary goals: (1) to provide guidance and focus for current and future efforts to incorporate pollution prevention principles and programs in existing EPA regulatory and nonregulatory programs, and (2) to set forth a program that will achieve specific pollution prevention objectives within a reasonable timeframe.

The PPA has five major provisions (Sections 6604-6608) that address developing and implementing a national source reduction program. Section 6604 sets out a comprehensive list of activities that the EPA Administrator is to develop as part of a strategy to promote source reduction. Some of these activities include:

- Developing standardized methods of measuring source reduction
- Coordinating source reduction activities within EPA and with other federal agencies
- Facilitating the adoption of source reduction programs by industry using the Pollution Prevention Clearinghouse and state matching grants
- Identifying measurable source reduction goals and an implementation strategy for the goals
- Identifying current barriers to achieving source reduction and making recommendations to Congress for overcoming these barriers
- Developing source reduction auditing procedures to help identify source reduction opportunities in the public and private sectors.

Section 6605 of the PPA directs EPA to establish a matching grant program for states to promote the use of source reduction by industry.

Section 6606 requires EPA to establish a pollution prevention clearinghouse to compile information on management, technical, and operational approaches to source reduction in a computerized format. The Clearinghouse was directed to serve as a center for source reduction technology transfer; develop and implement outreach and source reduction programs to encourage states to adopt source reduction practices; and collect and compile information on the operation and success of state source reduction programs operated under the matching grant program.

Section 6607 requires each owner and operator of a facility required to comply with the reporting requirements of SARA, Sec. 313 (toxic chemicals) to file an annual toxic chemical source reduction and recycling report with EPA. The report must address such topics as: the quantity of chemical entering any wastestream; the amount of chemical that is recycled and the process used; any source reduction activities associated with specific chemicals; projected amounts of the chemical(s) that will be reported for the next two calendar years; a comparison of chemical production figures from the previous and current reporting years; any techniques used to identify source reduction opportunities; the quantity of chemicals released as a result of catastrophic events, remedial actions, or other one-time events; and a comparison with similar data from the previous reporting year.

Section 6608 requires EPA to provide a biennial report to Congress that summarizes the data collected under the provisions of PPA section 6607. The congressional report must contain industry-specific evaluations of source reduction trends by industry; usefulness and validity of data in measuring trends in source reduction, and the adoption of source reduction programs by businesses; identification of regulatory and nonregulatory barriers to source reduction, and opportunities to use existing regulations and programs to encourage source reduction; identification of both industries and pollutants that require assistance in multimedia source reduction; identification of incentives needed to encourage research and development in source reduction technologies; and an evaluation of the technical feasibility and associated costs of source reduction, and the identification of those specific industries for which there exist significant barriers to source reduction.

A significant amount of progress has been made in implementing the PPA. In addition to reorienting U.S. environmental programs, the PPA has prompted the creation of programs such as the 33/50 program, which promotes waste reduction in the metal plating industry as well as others, and is responsible for the development and exchange of a substantial quantity of technical and cost data pertaining to pollution prevention. The information exchange system contains numerous case studies assessing specific pollution prevention projects undertaken by, or applicable to, the metals plating industry.

C.1.2 The Resource Recovery & Conservation Act

The Resource Conservation and Recovery Act (RCRA) addresses the management of solid waste, hazardous waste, and underground storage tanks that contain petroleum or hazardous substances. RCRA establishes a comprehensive cradle-to-grave regulatory scheme applicable to hazardous wastes. RCRA's hazardous waste provisions regulate wastes after they are generated and generally do not authorize EPA to regulate in-process materials. As such, RCRA does not provide extensive authority to mandate pollution prevention. RCRA does, however, provide some authority and incentives for addressing pollution prevention. In 1984, the Hazardous and Solid Waste Amendments (HSWA) added several new provisions to RCRA, some of which address pollution prevention. These provisions make it clear that pollution prevention is a fundamental element of U.S. hazardous waste management policy.

HSWA established prevention of the generation of hazardous waste as the national policy of the United States. This policy states that "wherever feasible, the generation of hazardous waste is to be reduced or eliminated as expeditiously as possible." This policy was clearly amplified in the Pollution Prevention Act of 1990. HSWA also mandated that hazardous waste generators and treatment, storage, and disposal facilities have waste minimization programs in place.

Under RCRA Sec. 6923(b) and Sec. 6925(h), hazardous waste generators and facilities that treat, store, or dispose of hazardous waste generated on-site are required to certify that they have a program in place to reduce the volume or quantity and toxicity of the materials that they manage. Such programs must exist to the extent that they are economically practical. Generators, including metal plating operations, must include such certifications on every hazardous waste manifest. Treatment, storage, and disposal facilities must have a requirement for such a program as a condition for their RCRA permit.

Wastewater treatment sludges are one of the waste products created during the metal finishing process. RCRA classifies these wastes and imposes technical standards for the treatment, storage, and disposal of each waste classification. Within RCRA Subtitle C, EPA has subcategorized hazardous wastes from non-specific sources in a series of "F" listings. For example, F006 includes wastewater treatment sludges from electroplating operations (specified processes are excluded). It is listed due to the presence of cadmium, hexavalent, chromium, nickel, and cyanide in the sludge. Other metal plating listed hazardous wastes include F001 (specified spent halogenated solvents used in degreasing), and F019 (wastewater treatment sludges from the chemical conversion coating of aluminum). Metal plating wastes can also be regulated as hazardous wastes if they posses a hazardous characteristic (per 40 CFR 261, Subpart C), particularly toxicity.

Under Subtitle C, hazardous wastes must meet stringent treatment standards prior to being land-disposed. In November 1992, EPA promulgated revisions to the treatment standards for spent solvents and electroplating wastewater treatment sludges. The revisions encourage recycling the metals in the sludge by allowing chromium and/or nickel-bearing electroplating sludges in high-temperature metal recovery units to meet land ban restrictions (as an alternative treatment standard).

C.1.3 The Clean Water Act

The Clean Water Act (CWA) was enacted to restore and maintain the chemical, physical, and biological integrity of the of the nation's waters. The act has five main components aimed at supporting these goals. The components are as follows: (1) technology-based, industry specific minimum national effluent (water discharge) standards; (2) water quality standards; (3) a permit program for discharges to U.S. water bodies; (4) specific provisions applicable to certain toxic and other pollutant discharges such as hazardous chemicals; and (5) a revolving Publicly Owned Treatment Works (POTW) construction loan program.

The primary purpose of these provisions is to ensure that toxic levels of pollutants are not discharged into the nation's waters by restricting the types and amounts of pollutants that are discharged. These restrictions are imposed through the use of enforceable effluent standards specified in National Pollution Discharge Elimination System (NPDES) permits. The NPDES permit program relies primarily on treatment to achieve compliance with discharge restrictions. The CWA does, however, contain provisions that are used to promote pollution prevention.

The most significant CWA components that encourage pollution prevention are the effluent discharge standards. These standards, which are developed for major industries, force regulated industries such as metal finishers to either reduce the amount of waterborne pollution that they generate or pay the cost of treatment. To facilitate waste reduction, EPA generally publishes in-plant controls as part of each effluent standard development document. In-plant controls include recommended changes to process engineering, process management, equipment, and manufacturing or processing systems.

The effluent guidelines and Standards for Electroplaters (40 CFR Part 413) and Metal Finishers (40 CFR Part 433) are under review. EPA is also currently developing effluent guidelines and standards for a related industry, the Metal Products and Machinery Industry (40 CFR Part 438), which are due by May 1996. Although this industry contains only cleaning and finishing operations as captive processes, it appears that EPA will integrate new regulatory options for the metal finishing industry processes into this guideline. Following the enactment of the Pollution Prevention Act, there is a renewed emphasis on fostering source reduction opportunities through these effluent guidelines.

C.1.4 The Clean Air Act

The Clean Air Act (CAA) was originally passed in 1967 and was last amended in 1990. The CAA was enacted to protect U.S. air quality by imposing emission standards on stationary and mobile sources of air pollution. Compliance with the requirements imposed under the CAA has generally relied upon the use of end-of-pipe controls. However, several provisions under the act do require or provide authority for pollution prevention.

As amended in 1990, the CAA established a list of 189 hazardous air pollutants (HAPs). Of the 56 substances from the Metal Finishing industry that were reported in the TRI database in 1990, 33 are included on the list of HAPs. Under the CAA, Congress required EPA to identify major and area source categories associated with the emission of one or more listed HAPs. To date, EPA has identified 174 categories of sources. Congress also required EPA to promulgate emission standards for listed source categories within 10 years of enactment of the CAA amendments (by November 15, 2000). These standards are known as National Emission Standards for Hazardous Air Pollutants (NESHAPs).

EPA is currently working on two NESHAPS that will directly affect the metal finishing industry and will provide clear opportunities for pollution prevention. These two activities are chromium electroplating and organic solvent degreasing/cleaning.

<u>Chromium Electroplating - NESHAP</u>

The chromium electroplating process emits a chromic acid mist in the form of hexavalent chromium and smaller amounts of trivalent chromium. Human health studies suggest that various adverse effects result from acute, immediate, and chronic exposure to hexavalent chromium. As a result, EPA has proposed a NESHAP (58 *FR* 65768, 12/16/93) for chromium emissions from hard and decorative chromium electroplating and chromium anodizing tanks.

These standards propose to limit the air emissions of chromium compounds in an effort to protect public health. The proposed regulation will be based on Maximum Achievable Control Technology (MACT) and will impose a performance standard limit on chromium and chromium compounds emissions based upon concentrations in the waste stream.

EPA suggests that these proposed performance standards allow a degree of flexibility since facilities may chose their own technology as long as the emissions standards (established by MACT) are achieved. The proposed standards differ according to the sources (e.g., old sources of chromium emissions will have different standards than new ones), further reducing the standards' rigidity through the recognition of diverse sources.

Organic Solvent Degreasing/Cleaning - NESHAP

EPA has also proposed a NESHAP (58 *FR* 62566, 11/29/93) for the source category of halogenated solvent degreasing/cleaning that will directly affect the metal finishing industry. This proposed standard aims at reducing halogenated solvent emissions to a MACT-equivalent level, and will apply to new and existing organic halogenated solvent cleaners (degreasers) using any of the HAPS listed in the CAA. EPA is specifically targeting vapor degreasers that use the following HAPs: methylene chloride, perchloroethylene, trichloroethylene, 1,1,1-trichloroethane (see also the International Section 4.7.1 concerning a ban under the Montreal Protocol), carbon tetrachloride, and chloroform.

This NESHAP proposes to implement a MACT-based equipment and work practice compliance standard (the CAA provides EPA with authority to establish stringent emissions limits as well as to require process or material modification as necessary to reduce risk). This would require that a facility use a designated type of pollution prevention technology along with proper operating procedures. However, EPA has also provided an alternative compliance standard. Existing operations, which utilize performance-based standards, can continue in place if they can be shown to reach the same limit as the equipment and work practice compliance standard.

Ozone Depleting Substances

The CAA also contains provisions addressing ozone protection requirements. The Act creates Class I and Class II substances and a phaseout schedule for each. The phaseout dates for Class I substances are the year 2000 for CFCs, halon, and carbon tetrachloride; 2002 for methyl chloroform (1,1,1-Trichloroethane). Class II substances (HCFCs) would be phased out by 2030. (President Bush mandated an acceleration of the phaseout schedule in 1992.) The CAA also mandates warning labels on products containing Class I or II substances and calls for the establishment of a safe alternatives program.

Numerous EPA regulations affecting the metal finishing industry have been promulgated under the CAA. For example regulations to implement the requirements of the Montreal Protocol were published in 1992 (57 *FR* 33754). The final rule concerning warning labels for Class I and II ODS was published by EPA in 1993 (58 *FR* 8136) and EPA's list of approved alternatives was published on March 18, 1994 (59 *FR* 13044). A listing of the industries affected by the warning label requirement was released by the EPA and included a broad range of manufacturing operations including metal finishing. Manufacturing facilities are required to determine if any Class I or II substances are used in their manufacturing operations and label their products accordingly. Many businesses are opting to substitute non-ODS substances for Class I or II substances to avoid the stigma of the labeling requirement.

C.1.5 Emergency Planning and Community Right-to-Know Act

Under the Emergency Planning and Community Right-to-Know Act (EPCRA), EPA has implemented the Toxics Release Inventory (TRI). This program, although not primarily focused on achieving pollution prevention, has created strong incentives for companies to reduce waste generation. The TRI requires companies within specified standard industrial classifications to report the quantities of certain toxic chemicals released to the environment. The release data, cumulatively known as the Toxic Release Inventory, is published by EPA. The TRI is intended to inform the public and industry of the nature and magnitude of toxic releases and to prompt increased scrutiny of such releases. It has resulted in substantial public pressure on companies to improve environmental performance as well as increased efforts by industry to improve efficiency, often through pollution prevention-based approaches. The TRI has also emerged as a primary mechanism used to measure pollution prevention, although there are acknowledged limits to its use in this capacity. The TRI indicates that between 1988 and 1992 the fabricated metals industry (SIC 34) reduced releases of TRI chemicals by 26.1 percent (137 million pounds to 101 million pounds). TRI data also identifies at least one chemical used by the metal plating industry as among the 10 chemicals released in the greatest quantity in the United States (1,1,1-Trichloroethane).

C.2 Enforcement

C.2.1 Innovative Environmental Enforcement Programs (SEPs)

EPA's commitment to vigorous enforcement of environmental law is reflected both in the significant expansion in recent years of its civil, criminal, and federal facility enforcement activities and its movement beyond traditional enforcement measures. EPA has moved beyond enforcement of media-specific laws to emphasize cross-program, multi-media enforcement. In addition, EPA has increased its use of creative enforcement techniques that use environmental enforcement authority to promote pollution prevention.

EPA's strong enforcement program encourages pollution prevention by providing incentives for industries to find ways to reduce its potential liabilities and response costs. In addition, the enforcement process is used directly against noncompliers to promote pollution prevention.

In 1990, EPA's Office of Enforcement developed a draft policy on including pollution prevention conditions in Agency settlements. When conducting negotiation the EPA may consider whether there are opportunities to correct an environmental violation through single or multi-media source reduction activities (e.g., reducing the source of emissions through changes in the industrial process or by production process input substitutions). Settlements are also used to encourage the respondent to undertake additional pollution prevention activities. Such innovative settlements are known as "supplemental environmental projects" (SEPs).

In February of 1991, James Strock, EPA Assistant Administrator, issued a memorandum to clarify the new Agency policy on the use of SEPs in Agency consent orders and decrees. This memorandum indicated that in settling environmental enforcement cases, the United States will insist upon terms which require defendants to achieve and maintain compliance with federal environmental laws and regulation. In certain instances, additional relief in the form of projects remediating the adverse public health or environmental consequences of the violations at issue may be included in the settlement to offset the effects of the particular violation which prompted the suit. As part of the settlement, the size of the final assessed penalty may reflect the commitment of the respondent to undertake SEPs. (Memorandum: Policy on the Use of Supplemental Enforcement Projects in EPA Settlements, to Regional Administrators, et al., from James Strock, February 12, 1991.)

In recent years, EPA has increasingly relied on the use of SEPs and a number of cross-media pollution prevention consent orders and decrees have been negotiated. For example, as part of a TSCA consent order, the 3-V Chemical Corporation agreed to install a solvent recycling system that is expected to reduce by 50 percent the point source emissions of 1,1,1-trichloroethane and dichloromethane. Although SEPs have been used most often in settlement of EPCRA violations, they have potential application to the metal finishing industry since it is subject to RCRA regulation and amenable to ample source reduction opportunities.

C.3 Voluntary Programs

USEPA has numerous voluntary programs aimed at educating, encouraging, and assisting industry and other entities in implementing pollution prevention programs and activities. A description of these programs follows.

C.3.1 EPA's 33/50 Program

EPA's 33/50 Program was announced early in 1991 as a voluntary pollution prevention initiative seeking to achieve significant reductions in pollution in a relatively short period of time. Under this program, EPA identified 17 high priority toxic chemicals selected from the Toxic Release Inventory (TRI) based on factors including high production volume, high releases and offsite transfers of the chemical relative to total production, opportunities for pollution prevention, and their potential for causing detrimental health and environmental effects.

EPA established a goal of reducing the total amount of these 17 chemicals released into the environment and transferred offsite by 33 percent by the end of 1992 and 50 percent by the end of 1995 (using 1988 as a baseline). EPA's goal is to achieve these reductions primarily through pollution prevention practices going beyond regulatory requirements. EPA is also encouraging industry to develop a source reduction approach and seeking to continue pollution prevention programs even beyond these chemicals and levels of reduction.

Success in the program will be measured by nationwide reductions rather than results at individual facilities or companies. EPA has contacted numerous companies, both large and small, with information on the 33/50 Program and to solicit their participation. Companies are being asked to identify and implement cost-effective pollution prevention practices related to the 17 chemicals and to develop written commitments stating their goals and plans to achieve them.

All of the 33/50 Program chemicals are regulated under one or more of the existing environmental statutes. The 33/50 Program is intended to complement, not replace ongoing programs. All 17 of the chemicals will be subject to the Maximum Achievable Control Technology (MACT) standards of the CAA. EPA believes that the incentive for early reductions offered by the MACT provisions will further the progress of the 33/50 Program.

The 17 target chemicals are list below (those in bold are chemicals typically generated by the metal plating industry):

- Benzene
- Cadmium & Cadmium Compounds
- Carbon Tetrachloride
- Chloroform (Trichloromethane)
- Chromium & Chromium Compounds
- Cyanide & Cyanide Compounds
- Lead & Lead Compounds
- Mercury & Mercury Compounds
- Methyl Ethyl Ketone
- Methyl Isobutyl Ketone
- Methylene Chloride (Dichloromethane)
- Nickel and Nickel Compounds
- Tetrachloroethylene (Perchloroethane)
- Toluene
- 1,1,1-Trichloroethane (Methyl Chloroform)
- Trichloroethylene
- Xylene.

It should be noted that on May 25, 1993, EPA officially released the TRI reporting data for 1991. One of the noteworthy findings revealed that releases and transfers of 33/50 Program chemicals declined by 34 percent from the 1988 baseline. That is to say, EPA surpassed the Program interim national goal of 33 percent reduction a full year ahead of schedule.

C.3.2 Waste Reduction Evaluations at Federal Sites (WREAFS)

The Department of Defense is cooperating with EPA and other federal agencies in the Waste Reduction Evaluation at Federal Sites (WREAFS) Program. The WREAFS Program has two primary objective. These objectives are to evaluate pollution generating processes at federal facilities for source reduction and recycling opportunities. The second objective is to enhance the adoption of pollution prevention and recycling through technology transfer to the public and private sector using project reports, project summaries, conference presentations, and workshops.

The WREAFS Program is essentially a series of assessments to find ways to reduce or prevent pollution. Some of the opportunities can be implemented by the facility without significant engineering changes. Other opportunities require research, development, and demonstration projects before options can be implemented. The technical and economic feasibility are also considered. Adoption of any recommendation is at the sole discretion of the facility.

Waste minimization opportunities have been identified under the WREAFS Program for numerous military and industrial processes for various federal agencies and DoD facilities. Some of these opportunities involve metal plating operations.

C.3.3 Design for the Environment

Since pollution prevention has gained in popularity, many firms are directing their environmental efforts earlier in the production cycle, often as far upstream as the product design process. The design stage is the most critical and effective time to address the environmental impacts. The design phase affords the greatest amount of flexibility in choosing everything from raw materials to manufacturing technique. Many aspects of Design for the Environment (DfE) have evolved out of the field of Industrial Ecology.

Recently, interest in Industrial Ecology and DfE have become more pronounced following the adoption of German legislation that requires manufacturers and retailers to collect and recycle packaging for a wide range of products. Firms will have to recycle 80 percent beginning in 1995. This type of policy development has led to increased scrutiny of how products are designed.

Major redesign efforts in international manufacturing have also been identified as a result of the Montreal Protocol, a treaty which requires industrial nations to discontinue production and use of most CFCs by 2000.

The DfE Program focuses on pollution prevention and environmental risk. DfE promotes the incorporation of environmental considerations and risk reduction in the design of products and services. The Program works on a voluntary basis through partnerships with industry and the public. It builds on voluntary EPA programs like the 33/50 Program.

The DfE Program has initiated a number of wide-ranging projects which operate through three levels of involvement:

1. Infrastructure projects are the broadest in scope and aimed at changing general business practices in order to remove barriers to behavioral change and to provide incentives for undertaking environmental design and pollution prevention efforts.
2. Industry projects are joint efforts with trade associations and businesses in specific industry segments to evaluate comparative risks, performance and costs of alternatives.
3. Facility-based program activities will help individual businesses undertake environmental design efforts of their own through the development and application of specific methods, tools, and models.

DfE uses analytical tools such as "use clusters" and "substitutes assessments" to examine alternatives. The DfE Program has developed a methodology for examining substitute chemicals, processes, and technologies. Through a process of collecting information on currently existing alternatives and through a search for other promising options the DfE Program lists all alternatives in a "use cluster tree" for chemicals, processes, and technologies that can substitute for one another in performing a particular function. In this way DfE systematically compares the trade-offs associated with given alternatives.

Cleaner Technology Substitutes Assessments (CTSAs) are intended to provide a flexible format for systematically comparing the trade-off issues associated with alternatives. Traditional trade-offs such as cost and performance are brought together with environmental trade-offs, including comparative risk, releases, energy impact and resource conservation for each alternative. EPA is working industry to provide guidance through the DfE Program. Several industry specific cooperative projects have already been undertaken.

EPA has begun a joint Metal Finishing DfE project with the Industrial Technology Institute and the Cleveland Advanced Manufacturing Program. This project is funded as a Technology Reinvestment Project, and its purpose is to develop an integrated Energy, Environment, and Manufacturing (EEM) assessment methodology for the metalworking industry.

The EEM assessment methodology is intended to be an auditing tool that will allow businesses to conduct energy, environment, and manufacturing audits. DfE will concentrate its efforts on metal finishing and will evaluate the comparative, multi-media risks of alternative chemicals, processes, and technologies. The DfE process begins with an evaluation of specific steps in metal finishing processes to target those of highest risk. In order to do this DfE will work through the Industrial Technology Institute to engage the metal finishing industry as a partner in the project. A metal finishing industry profile will be developed which will provide background information on the industry and help select target areas.

C.3.4 The Source Reduction Review Project (SRRP)

Section 4(b) of the Pollution Prevention Act of 1990 required EPA to "review regulations of the Agency prior and subsequent to their proposal to determine their effect on source reduction." In response to this charge, EPA created the Source Reduction Review Project (SRRP). SRRP is a major, Agency-wide initiative that is demonstrating the value and feasibility of taking a source reduction approach in designing environmental regulations. The Agency is conducting an in-depth analysis of source reduction measures and cross-media issues in the development of 24 rule-makings for air toxics (MACT standards), water pollution (effluent guidelines), and hazardous wastes (listing determinations).

The goal of the SRRP is to foster the use of source reduction measures as the preferred approach for achieving environmental protection, followed in descending order by recycling, treatment, and, as a last resort, disposal. The project will initially ensure that source reduction measures and multi-media issues are considered in the development of forthcoming air, water, and hazardous waste standards affecting 17 industrial categories.

Notwithstanding the inclusion of source reduction approaches in the past, SRRP will emphasize rigorous technical and economical analysis as the means for incorporating source reduction into regulations, as well as on coordinating a multi-media approach to rulemaking.

For the Degreasing MACT Standard, SRRP is considering a regulatory option of an equipment/work practice standard with a solvent consumption indicator. Also, an alternative under consideration is an idling emissions limit with an overall solvent use limit. Almost all measures that are being considered as the basis of the equipment standard option are source reduction measures. The alternative standard would provide flexibility to encourage technological innovation.

C.3.5 Pollution Prevention Grants

USEPA provides grants to support pollution prevention efforts to states and initiates jointly funded grant programs with other federal agencies. The centerpiece of EPA's pollution prevention grant activities for the last several years is an ongoing program know as Pollution Prevention Incentives for States (PPIS). PPIS is intended to build and support state pollution prevention capabilities and to provide an opportunity to test innovative approaches and methodologies at the State level.

Section 5 of the Pollution Prevention Act of 1990 authorizes EPA to make matching grants to states to promote the use of source reduction techniques by business. Eligible participants include states (including State Universities) and federally recognized Indian tribes. Local governments, private universities, private non-profit groups, businesses, and individuals are not eligible. However, organizations excluded from applying directly are encouraged to work with eligible State agencies in developing proposals that would include them as participants in the projects.

EPA strongly encourages this type of cooperative arrangement.

In general, the purpose of PPIS is to support the establishment and expansion of State-based pollution prevention programs. Organizations receiving grants are required to match federal funds by at least 50 percent. State contribution may include dollars and/or in-kind goods and services. For example, the State of Massachusetts, Department of Environmental Management has awarded a grant to expand their technical assistance source reduction program. Their pilot project included training, workshops and development of a financial feasibility model for use by company managers to determine the cost effectiveness of source reduction and recycling alternatives focusing on electroplaters and metal finishers.

In addition, EPA provides between 600 and 800 million dollars each year for specific media grants to states and/or regions. These grants help support states to implement federal programs like the Clean Water Act, the Clean Air Act, and RCRA. Pollution Prevention Grant Guidance, in effect since November of 1992, provides states with the flexibility to use these funds to support multi-media pollution prevention initiatives to the extent permitted by statute or regulation.

EPA also enters into jointly funded grants with other federal agencies. One example is EPA's National Industrial Competitiveness Through Efficiency: Energy, Environment and Economics ($NICE^3$). $NICE^3$ is a joint project with the Department of Energy and EPA to provide grants to improve energy efficiency, advance industrial competitiveness, and reduce environmental emissions by industry. Large-scale research and demonstration projects are targeted at industries with the highest energy consumption and greatest levels of toxics and chemicals released. An example is a recent $NICE^3$ project to develop UV-curable coatings for aluminum can production.

C.3.6 Technology/Policy Transfer - PPIC/ICPIC/OzonActon

Section 6606 of the Pollution Prevention Act of 1990 required EPA to establish a pollution prevention clearinghouse to compile information on management, technical, and operational approaches to source reduction in a computerized format. The clearinghouse was directed to serve as a center for source reduction technology transfer, develop and implement outreach and source reduction programs to encourage states to adopt source reduction practices, and collect and compile information on the operation and success of source reduction programs.

New technologies are emerging daily and regulatory pressures on industry create the need for a rapid and efficient transfer of information. The Pollution Prevention Information Clearinghouse (PPIC) and its on-line bulletin board/database component called the Pollution Prevention Information Exchange System (PIES) were created by EPA to facilitate this flow of information to industry, government policy makers, and the public.

PPIC is a free clearinghouse service that consists of a repository of technical, policy, legislative, and programmatic information concerning pollution prevention and recycling. The PPIC repository also contains a hotline service to refer questions and take document orders. PIES is a 24-hour electronic network accessible by personal computer and modem which is free to all users. PIES contains an interactive message center where pollution prevention professionals can communicate; bulletins; a calendar of events concerning cleaner production and pollution prevention seminars, workshops, and conferences; program summaries; a directory of experts; and technical information in the form of fact sheets and case studies highlighting pollution prevention techniques. Numerous case studies and fact sheets relevant to the metal finishing industry are available through PPIC and PIES.

PIES has become a global information network and provides a unified access point for related electronic networks. PIES is now electronically linked to similar systems such as the United Nations Environmental Programme's (UNEP) International Cleaner Production Information Clearinghouse (ICPIC) and the UNEP OzonAction Information Clearinghouse. These systems support global exchange of pollution prevention information and alternatives to ozone depleting substance alternatives and technologies. All of these systems contain technical and policy information relevant to the plating industry for large and small applications.

C.4 State Programs

State programs are summarized by State in **Exhibit C-1**. This exhibit provides the State's status, program definition, materials, priorities, who is covered, policies, what information is accessible, and the funding.

Exhibit C-1. Common Elements of State Pollution Prevention Plans

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
Alaska Voluntary enacted '90	Management: – solid and hazardous waste No statewide numeric goals		Includes: – source reduction – recycling – treatment – disposal Excludes: – incineration – media transfer	Not specified	– Technical assistance – Education – Grants – Information referral		Appropriations
Arizona Mandatory enacted '91	Pollution Prevention – toxic use reduction – source reduction No statewide numeric goals	Hazardous and Toxic Waste	Includes: – toxic use reduction – source reduction – input, process, product change – ℞safe" treatment	Includes: – SARA reporters – large quantity generators	– Facility plans – Annual reports – Technical Assistance Program – Hazardous Waste Management Fund	Plans are confidential at request of owner	Based on fees
California Mandatory enacted '89	Reduction: – source – waste – release No statewide numeric goals	California hazardous and extremely hazardous wastes	Includes: – input, process, product change Excludes: – treatment – media transfer – volume change	Includes: – large-quantity generators Excludes: – those claiming infeasibility of options	– Facility plans – Performance reports – Pilot SIC codes – technical assistance	Plans/reports available to public; trade secrets available only to state	Based on fees and penalties
Colorado Voluntary enacted '92	Pollution Prevention – any practice that reduces use or generation	SARA Title III and CERCLA	Includes: – input, process, product change Excludes: – recycling – treatment – disposal	All business and government Focuses on small and medium-sized businesses	– Advisory Board – Pollution Prevention Fund – technical assistance		Based on fees

Exhibit C-1. Common Elements of State Pollution Prevention Plans (Continued)

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
Connecticut Voluntary enacted '91	Pollution Prevention: – generation – hazardous and toxic waste – multi-media No statewide numeric goals	Hazardous and Toxic Waste (not specified)	Includes: – input, process, product change Excludes: – incineration – media transfer – off-site or out of process recycle	Businesses with gross revenues of less than $25 million or less than 150 employees	– Technical assistance – Grant program		General Fund
Delaware Voluntary enacted '90	Minimization: – hazardous and solid waste – multi-media reduction No statewide numeric goals	Delaware Code – solid/liquid/ hazardous/ refuse – air pollutants – sewage	Includes: – waste reduction – reuse and recycle – sound treatment and disposal	Industries and sites targeted at annual intervals Voluntary waste minimization planning	– Technical assistance – Information clearinghouse – Public education – Statewide recycling program	Trade secrets are protected	Not based on fees
Florida Voluntary enacted '91	Pollution Prevention: – at the source No statewide numeric goals	Toxics (not specified)	Includes: – input substitution and reduction (including energy) – product reform – process change – procedure change – environmental planning for facility expansion – on-site recycling	LQGs, SQGs and toxics users pay annual fee	– Technical assistance – Conferences	Proprietary information obtained through on-site technical assistance is confidential	General Fund

Exhibit C-1. Common Elements of State Pollution Prevention Plans (Continued)

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
Georgia Mandatory enacted '90	Reduction: – hazardous waste No statewide numeric goals	Georgia hazardous and acute hazardous waste	Includes: – input, process, product change in-house recycle Excludes: – treatment – media transfer – volume change – incineration	Includes: – large quantity generators – out-of-state large quantity generators using Georgia TSDs	– Technical assistance – Facility planning	Plans/reports available to public; trade secrets available only to state	Not based on fees
Illinois Voluntary enacted '89	Prevention: – toxic pollution No statewide numeric goals	SARA toxic substances and Illinois lists	Includes: – input, process, product change in-house recycle Excludes: – treatment – media transfer – volume change – incineration	Voluntary and pilot (Cooperation on permits) – generators	– Technical assistance – Innovation – Inspectors' manual – Explore enforcement – Research (HWRIC)	Trade secrets protected	General fund and money raised by HWRIC activity
Indiana Voluntary enacted '90	Prevention is reduction of: – toxic material use – waste release No statewide numeric goals	CERCLA hazardous substances and Indiana "environmental wastes"	Includes: – input, process, product change in-house recycle Excludes: – off-site recycle – media transfer – incineration	Voluntary and pilot	– Technical assistance – Research – Grants – Generator planning manual	Trade secrets protected	General fund

Exhibit C-1. Common Elements of State Pollution Prevention Plans (Continued)

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
Iowa Voluntary enacted '91	Prevention: toxics pollution No statewide numeric goals	Iowa lists which include SARA, RCRA	Includes: – input, process, product changes, integral recycle Excludes; – burning, transfer off-site recycle, exchange	Includes: – SARA reporters – LQGs	– Facility plans and summaries (voluntary) – Technical assistance – Information	Plans submitted to the Waste Management Authority for review and approval	General fund
Kentucky Voluntary enacted '88	Reduction: – toxic waste generation No statewide numeric goals	RCRA, SARA	Includes: – input, process, product change in-house recycle Excludes: – off-site recycle or treatment – volume change	Voluntary: – RCRA and SARA report data collected	– Technical assistance – Information – Training – Grants – Set state goals	Trade secrets protected	General fund
Louisiana Mandatory enacted '87	Reduction: – hazardous and solid waste No statewide numeric goals	RCRA	Includes: – in-plant practices – in-process recycling Excludes: – off-process or off-site recycle toxicity change	Includes: – large-quantity generators	– Waste reduction reports and plans (done) – Technical assistance – Fee structure promoting reduction	Public data laws apply	Based on fees and the general fund
Maine Mandatory enacted '90 amended '92	Reduction: – toxics use – toxics release – hazardous waste Statewide goal-use reduction: – 10% by 7/1/93 – 20% by 7/1/95 – 30% by 7/1/97	SARA toxics, RCRA	Includes: – input, product or process changes – capture for reuse, recycling treatment	Includes: – large-quantity generators – small-quantity generators – toxics users Excludes: – some LQGs, POTWs	– Facility plans and reports – Information program – Advisory committee – Technical services – Grants	Plans available to state	Based on fees

Exhibit C-1. Common Elements of State Pollution Prevention Plans (Continued)

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
Massachusetts Mandatory enacted '90	Reduction: – toxics use and/or release Statewide goal-waste reduction: – 50%	SARA toxics, CERCLA	Includes: – input, product or process change Excludes: – incineration – media transfer – treatment – off-site recycle	Includes: – large-quantity toxics users – small-quantity toxics users Excludes: – facilities <10 employees	– Facility plans and reports – Toxics use planners – Toxics use survey – Technical assistance	Public petition for review of plan summary and report – plans are public; trade secrets protected	Based on fees
Michigan Voluntary enacted '87	Reduction: – any practice that reduces release or treatment	Hazardous, Solid, Liquid Industrial Waste, and Air Contaminants	Includes: – input, product or process change – improved management, training and/or inventory control	Michigan businesses, governmental units, and the general public	– Technical assistance	Information generated through grant programs is available to the public	Not based on fees
Minnesota Mandatory enacted '90	Prevention: – toxic pollutants use, release generation No statewide numeric goals	SARA toxics	Includes: – input, product or process change – reduction in releases	Includes: – SARA reporters – large-quantity generators (fees only)	– Facility plans and reports – Guidance manual – Technical assistance – Grants	Public petition for review of progress reports – plans are protected	Based on fees
Mississippi Mandatory enacted '90	Minimization: – hazardous waste Statewide goal-waste reduction – 25% by 1/1/96	Any USEPA-listed hazardous waste	Hierarchy: 1. Source reduction 2. Waste reduction 3. Recycling 4. Treatment 5. Disposal	Includes: – large-quantity generators – small-quantity toxics users – SARA reporters	– Facility plans and reports – Technical assistance – Training – Research – Explore new statutes	Plans may be made available to public; trade secrets are protected	Based on fees

Exhibit C-1. Common Elements of State Pollution Prevention Plans (Continued)

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
New Jersey Mandatory enacted '91	Prevention: – hazardous substance pollution Statewide goal-discharge reduction – 50% by 1996	SARA Title III Section 313 toxics	Includes: – input, process, product change, in-house recycle Excludes: – off-site recycle or treatment – incineration – increased pollution, control	Priority facilities in selected SIC codes in 3 years. Others may be required by DEP	– Facility-wide permitting – Facility plans and summaries – Training	Trade secrets available to state, but not pubic	Based on fines and general fund
New York Mandatory enacted '90	Reduction: – hazardous waste, toxic substance release and generation Statewide goal-waste reduction: – 50% by 1999	SARA, RCRA	Includes: – input, process, product change, in-house, closed-loop or off-site recycling	Includes: – current permit holders – generators of 25 tons and up	Facility plans and reports – Guidance manual – Evaluation	Public data rules apply	Based on fines and general fund
Oregon Mandatory enacted '90	Reduction: – toxics use – hazardous waste generation No statewide numeric goals	SARA, RCRA	Includes: – input, process, product change, in-house, closed-loop or off-site recycling	Includes: – SARA reporters generators: – conditionally exempt – fully regulated – small-quantity	– Facility plans, reports and summaries – Technical assistance – Training – Information	Summaries are public record except trade secrets: plans and reports stay on-site	Based on fees
Rhode Island Voluntary enacted '89	Planning for: – hazardous waste facilities No statewide numeric goals	RCRA, Rhode Island lists of ℞hard-to-dispose" materials		Includes: – all users of hazardous waste facilities	– Technical assistance – Education – Research – Grants		Based on fees and general fund

Exhibit C-1. Common Elements of State Pollution Prevention Plans (Continued)

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
South Carolina Voluntary enacted '91	Reduction: – toxics use – toxics generation Statewide goal-waste reduction: – 50% by 1998	SARA, CERCLA, SC lists	Includes: – input, process, product change, in-house or closed-loop recycling Excludes: – incineration – treatment – off-site recycle – media transfer	Includes: – toxics users in selected SIC codes, small or large – POTWs	– Facility plans, reports and summaries – Technical assistance – Outreach and training – Classify units of production	– Citizen petition – Trade secrets protected	Based on fees
Tennessee Mandatory enacted '90	Reduction: – hazardous waste Statewide goal-waste reduction: – 25% by 6/3/95	RCRA	Includes: – in-process recycling or changes in process or inputs	Includes: – small-quantity generators – large-quantity generators	– Facility plans, reports and summaries – Technical assistance – Civil fines	– Summaries are public; plans and reports are not	General fund
Texas Mandatory enacted '91	Reduction: – source Minimization: – hazardous waste No statewide numeric goals	SARA III 313 RCRA	Includes: – input, process, production change Excludes: – any process not integral to the production that alters the waste	Includes: – SARA reporters – Large-quantity generators	– Facility plans, reports and summaries – Governor's Award – Permit variance – Information – conferences – Training – Waste Audits	– Summaries and reports are public; plans are not – Board can declare plan confidential	Based on fees

Exhibit C-1. Common Elements of State Pollution Prevention Plans (Continued)

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
Vermont Mandatory enacted '90	Management and Reduction: – source – toxics use Establish and adopt a statewide goal	SARA, RCRA	Includes: – input, process, product change, closed-loop recycling Excludes: – incineration – treatment – volume change – media transfer	Includes: – small-quantity generators – large-quantity generators – household generators	– Facility plans and reports – Study of toxic use reduction – Tax RCRA generators – Technical assistance – Research – Retail labeling	– Trade secrets are protected	Based on fees
Virginia Mandatory enacted '93	Prevention: – at the source – environmental waste	All wastes	Includes: – input, process, product change – closed-loop recycling Excludes: – treatment – incineration – out of process recycling – increased control	Includes: – small businesses – local governments	– Technical assistance – Waste exchange – Grants		General funds
Washington Mandatory enacted '90	Reduction: – hazardous waste – hazardous substance use Statewide goal-waste reduction – 50% by 1995	SARA, WA lists, Montreal Protocol (ozone-depleaters)	Includes: – input, process, production change, closed-loop recycling Excludes: – incineration – media transfer	Includes: – all hazardous waste generators regulated by WA – SARA reporters	– Facility plans and summaries (voluntary impl.) – Fees/penalties – Technical assistance – Research – Training	– Summaries and reports are public; plans are not – Competitive position protected	Based on fees

Exhibit C-1. Common Elements of State Pollution Prevention Plans (Continued)

State/Status	Definitions	Materials	Priorities	Coverage	Policies	Access	Funding
Wisconsin Voluntary enacted '89	Use and Release Reduction: – toxic pollutants – hazardous waste and substances Pollution Prevention No statewide numeric goals	SARA, RCRA	Includes: – input, process, product change, closed-loop recycling Excludes: – incineration – treatment – out-of process recycling – media transfer	Voluntary Includes: – hazardous waste generators – hazardous substance users	Voluntary – Waste audits – Research – Grants Mandatory – Waste min. documentation on manifests and reports		General fund

APPENDIX D—POLLUTION PREVENTION CONTACTS

D.1 U.S. EPA Program Contacts

D.1.1 Agriculture in Concert With the Environment (ACE)

For general information on the ACE program, contact:

Harry Wells
Office of Pollution Prevention (7409)
U.S. EPA
401 M. Street, SW
Washington, DC 20460
202-260-4472

G.W. Bird
Director, USDA Sustainable Agriculture
Research and Education Program
342 Aerospace Building
14th and Independence Avenues
Washington, DC 20250

Patrick Madden Ph.D.
Associate Director, USDA Sustainable Agriculture
Research and Education Program
P.O. Box 10338
Glendale, CA 91209

D.1.2 National Industrial Competiveness Through Efficiency: Energy, Environment and Economics (NICE^3)

Eligible industries are in SIC Codes 26 (paper), 28 (chemicals), 29 (petroleum and coal products), and 33 (primary metal industries).

For more information, contact:

David Bassett
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
401 M Street, SW (7409)
Washington, DC 20460
202-260-2720

D.1.3 Pollution Prevention Incentives for States (PPIS)

National Eligibility Criteria

- Must be pollution prevention as defined by the Act.
- Multimedia opportunities and impacts should be identified.
- Areas for significant risk reduction should be targeted.
- Other pollution prevention efforts in the state should be leveraged and integrated into the project.
- Measures of success are identified.
- A plan for dissemination of project results should be identified.

Along with the National Eligibility Criteria, regional pollution prevention offices may develop their own region specific guidance. *Interested applicants should contact their regional pollution prevention coordinator for more information.*

Headquarters contact:
Lena Hann
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
401 M. Street, SW (TS-779)
Washington, D.C. 20460
202-260-2237

D.1.4 33/50 Program

Announced early in 1991, EPA's 33/50 Program is a voluntary pollution prevention in a relatively short period of time.

Under this program, EPA has identified 17 high priority toxic chemicals. EPA's Administrator has set a goal of reducing the total amount of these chemicals released into the environment and transferred offsite by 33 percent at the end of 1992 and by 50 percent at the end of 1995.

For More Information:

For copies of a brochure on the 33/50 Program or other information, fax your request to the TSCA Assistance Service at 202-554-5603. Or call the TSCA Hotline at 202-554-1404 from 8:30 a.m. to 4:00 p.m. EST. Also, computer users may access the 33/50 mini-exchange in PIES (see Section 7 on PIES).

D.1.5 Design for the Environment (DfE)

Established in October 1992, EPA's Design for the Environment Program (DfE) is a voluntary cooperative program which promotes the incorporation of environmental considerations, and especially risk reduction, at the earliest stages of product design.

DfE Program has initiated a number of wide-ranging projects which operate through two levels of involvement. Industry Cooperative projects work with specific industry segments to apply substitute assessment methodology, share regulatory and comparative risk information, and invoke behavioral change Infrastructure projects are aimed at changing aspects of the general business environment which affect all industries in order to remove barriers to behavior change and provide models which encourage businesses to adopt green design strategies.

EPA's DfE Program is working closely with trade associates and individuals in three-specific industry segments. These cooperative projects will develop Substitutes Assessments, which compare risk and environmental trade-offs associated with alternative chemicals, processes, and technologies and which will provide models for other businesses to follow when including environmental objectives in their designs.

The DfE Program has awarded 6 grants to universities which fund research into alternate synthesis of important industrial chemical pathways. Results of the research will provide the chemical industry with tools for production which reduce risk and prevent pollution. The grants are providing a model for further National Science Foundation grants.

For more information contact:

Pollution Prevention Information Clearinghouse
U.S. Environmental Protection Agency
401 M. Street, SW (PM-211A)
Washington, DC 20460
202-260-1023

DfE Metal Finishing Project

Contact: Brian Sweeney, 202-260-0702

Source Reduction Review Project

Degreasing MACT Standard: Analysis of Potential substitutes to halogenated solvents will inform industry of any potential cross-media impacts that might result from solvent substitution.

Contact: Paul Almodovar, 919-541-0283;
Chuck Darvin, 919-541-7633

Office of Solid Waste:
Haile Marian
U.S. EPA
401 M Street, S.W. 5302W
Washington, DC 20460
Phone: (703) 308-8439
Fax: (703) 308-8433

D.2 U.S. EPA Regional Office Pollution Prevention Contacts

The individuals identified below are the official contacts for pollution prevention matters concerning the EPA Regional Office initiatives and the 33/50 Program. Summaries of each Region's pollution prevention activities can be found in the Pollution Prevention Information Exchange System (described in section 7).

Region I

Mark Mahoney, Manager
Abby Swaine, Manager
Pollution Prevention Program
U.S. EPA Region I (PAS)
John F. Kennedy Federal Building
Boston, Massachusetts 02203
Mahoney: Phone: 617-565-1155
Fax: 617-565-3346
Swaine: Phone: 617-565-4523
Fax: 617-565-3346

Dwight Peavey
33/50 and ENERGI Programs
U.S. EPA Region I (ATR)
John F. Kennedy Federal Building
Boston, Massachusetts 02203
Phone: 617-565-3230
Fax: 617-565-4939

Norman Willard
Green Lights and ENERGI Programs
U.S. EPA Region I (ADA)
John F. Kennedy Federal Building
Boston, Massachusetts 02203
Phone: 617-565-3243

D.2.1 Region II

Janet Sapadin, Pollution Prevention Coordinator
U.S. EPA Region II
26 Federal Plaza, Rm. 900
New York, New York 10278
Phone: 212-264-1925
Fax: 212-264-9695

Nora Lopez
33/50 Program
U.S. EPA Region II (MS: 105)
2890 Woodbridge Avenue, Building 10
Edison, New Jersey 08837-3679
Phone: 908-906-6890
Fax: 908-321-6788

D.2.2 Region III

Lorraine Urbiet
Pollution Prevention Coordinator
Environmental Assessment Branch
Environmental Services Division
U.S. EPA Region III
841 Chestnut Building (3ES43)
Philadelphia, Pennsylvania 19107
Phone: 215-597-6289
Fax: 212-597-7906

Billy Reilly
33/50 Program
Special Assistant, Air, Radiation, & Toxics Division
U.S. EPA Region III (3AT01)
841 Chestnut Building
Philadelphia, Pennsylvania 19107
Phone: 215-597-9302
Fax: 215-349-2011

D.2.3 Region IV

Carol Monell
Chief, Pollution Prevention Unit
Policy, Planning, and Evaluation Branch
Office of Policy and Management
U.S. EPA Region IV
345 Courtland Street, NE
Atlanta, Georgia 30365
Phone: 404-347-7109
Fax: 404-347-1043

Beverly Mosely
33/50 Program
U.S. EPA Region IV
345 Courtland Street
Atlanta, Georgia 30365
Phone: 404-347-1033
Fax: 404-347-1681

D.2.4 Region V

Kathy Allon
Pollution Prevention Coordinator
Planning and Budgeting Branch
Policy and Management Division
U.S. EPA Region V
77 West Jackson Blvd.
Chicago, Illinois 60604-3590
Phone: 312-886-2910
Fax: 312-886-5374

Dennis Wesolowski
33/50 Program
Acting Chief, Asbestos Control Section
Environmental Science Division
U.S. EPA Region V (MS: SP-14J)
77 W. Jackson Blvd.
Chicago, Illinois 60604
Phone: 312-353-5907
Fax: 312-353-4342

D.2.5 Region VI

Dick Watkins, Pollution Prevention Coordinator
Donna Tisdall, Grants Coordinator
Office of Planning and Evaluation
U.S. EPA Region VI
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D.2.7 Region VIII

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D.2.8 Region IX

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D.2.9 Region X

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D.3 Pollution Prevention Information Clearinghouse

The Pollution Prevention Information Clearinghouse (PPIC) is dedicated to reducing or eliminating industrial pollutants through technology transfer, education, and public awareness. It is a free, nonregulatory service of the U.S. EPA, and consists of: a repository, a telephone reference and referral service and a computerized information exchange system.

Telephone service is available to answer or refer questions on pollution prevention or the PPIC and take orders for documents distributed by the PPIC.

Phone: 202-260-1023
Fax: 292-260-0178
Mail: Pollution Prevention Information Clearinghouse
Environmental Protection Agency, PM 211-A
401 M Street, SW
Washington, DC 20460

D.3.1 Enviroene

Anyone can access Enviroene using either an IBM PC (or compatible), Apple, or a dumb terminal equipped with a modem (2400 or 14,400 baud), and appropriate communications software. Enviroene is accessible through a regular telephone call, the SprintNet network and the EPA × .25 wide area network (for EPA employees only). The following communications software settings are required if you are calling Enviroene on a regular telephone line:

Phone Number:	703-908-2092
Speed:	2400 or 14,400
Data Bits:	8
Parity:	None
Stop Bits:	1
Emulation:	ANSI or VT-100

A short, 2-page, "Enviroene Quick Reference Guide" was written to help new users log-on to and use the system. This guide can be requested by calling the Enviroene technical support office. An Enviroene User Guide is available and may be obtained free of charge by leaving a message on the system addressed to "Sysop", or by writing or calling the Clearinghouse.

Phone: 703-821-4800
Fax: 703-821-4775

D.3.2 International Cleaner Production Information Clearinghouse (ICPIC)

The International Cleaner Production Information Clearinghouse (ICPIC) is the PPIC's sister clearinghouse operated by the United Nations Environment Program (UNEP). The ICPIC provides information to the international community on all aspects of low- and non-waste technologies and methods. Patterned after the PPIC, the ICPIC has similar functions and components, including an electronic information exchange system that is indirectly accessible to PIES users through nightly exchange of messages on the PIES Main Menu message center. For more information about the ICPIC, contact the PPIC (see above) or the ICPIC at the address below.

Jacqueline Aloisi de Larderl, Director
United Nations Industry and Environment Office
39-43 quai André Citröen
75739 Paris CEDEX 15
France
33-1-44-3714-50
33-1-44-3714-74 Fax

D.3.3 OzonAction

OzonAction was newly established by UNEP in 1992 under the Interim Multilateral Ozone Fund (IMOF) of the Montreal Protocol Agreements. OzonAction relays technical and programmatic information on alternatives to all ozone depleting substances identified by the IMOF. OzonAction contains information on five industry sectors: solvents, coatings and adhesives; halons; aerosols and sterilants; refrigeration; and foams. Later this year OzonAction will contain the OZONET data bases on solvent substitutes, compiled by the Industry Cooperative for Ozone Layer Protection (ICOLP). For more information on OzonAction, contact the director, UNEP Industry and Environment Office listed above.

Jacqueline Alois de Larderl, Director
United Nations Industry and Environment Office
39-43 quai André Citröen
75739 Paris CEDEX 15
France
33-1-44-3714-50
33-1-44-3714-74 Fax

D.3.4 American Institute for Pollution Prevention (AIPP)

The AIPP was founded jointly by U.S. EPA and the University of Cincinnati in 1989 to assist EPA in promoting the widespread and expeditious adoption of pollution prevention concepts. The institute accomplishes this mission through developing informational and educational materials; participating in waste reduction demonstration projects; conducting economic, programmatic, and technological analyses; and assisting government, universities, and industry in identifying and resolving various pollution prevention issues. The institute consists of a group of 25 volunteer experts selected by their professional societies, agencies, and trade associations. These experts participate in four councils that undertake various tasks: Economics Council, Education council, Implementation Council, and Technology Council.

Thomas R. Hauser, Ph.D., Executive Director
American Institute for Pollution Prevention
Department of Civil and Environmental Engineering
University of Cincinnati
Cincinnati, Ohio 45221-0071
Phone: 513-556-3693

D.3.5 The National Roundtable of State Pollution Prevention Programs (Roundtable)

The Roundtable is a group of pollution prevention programs at the State and local level in both the public and academic sectors. Typically, member programs are engaged in a broad range of activities, including multi audience training and primary to post-secondary pollution prevention education, supported by a variety of State and Federal funding sources. The roundtable is coordinated through biannual conferences as well as ongoing activities. Conferences serve in part as opportunities for updates on member programs' progress, including their training efforts. The first conference in 1993 is scheduled for April 28-30. (October conference TBA) The Roundtable is funded through a U.S. EPA grant.

David Thomas
National Roundtable of Pollution Prevention Programs
One East Hazelwood Drive
Champaign, Illinois 61820
Phone: 217-333-8940
Fax: 217-333-8944

D.3.6 Waste Reduction Institute for Training and Applications Research, Inc. (WRITAR)

WRITAR is a private, independent, nonprofit organization designed to identify waste reduction problems, help find their solutions, and facilitate the dissemination of this information to a variety of public and private organizations. The institute is also the current administrator of the U.S. EPA grant to the National Roundtable of State Pollution Prevention Programs (see above). WRITAR has an extensive background in designing and delivering persuasive pollution prevention training to Federal, State, and local regulators, inspectors, and administrative staffers, and well as to corporate and public audiences. This existing activity is supplemented by a 1991 grant from the U.S. EPA Office of Pollution Prevention to support pollution prevention training for the States through U.S. EPA Regional staff. WRITAR also conducts industry-specific training (primarily in metal finishing) for more narrowly defined audiences.

Terry Foecke or Al Innes
Waste Reduction Institute for Training and Applications Research
1313 5th Street, S.E.
Minneapolis, Minnesota 55414-4502
Phone: 612-379-5995

Fax: 619-379-5996

D.4 OECD Waste Minimization Workshop Participants

OECD/OCDE PREPARATORY MEETING FOR THE WASTE MINIMIZATION WORKSHOP, 26 July 1994

D.4.1 List of Participants

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